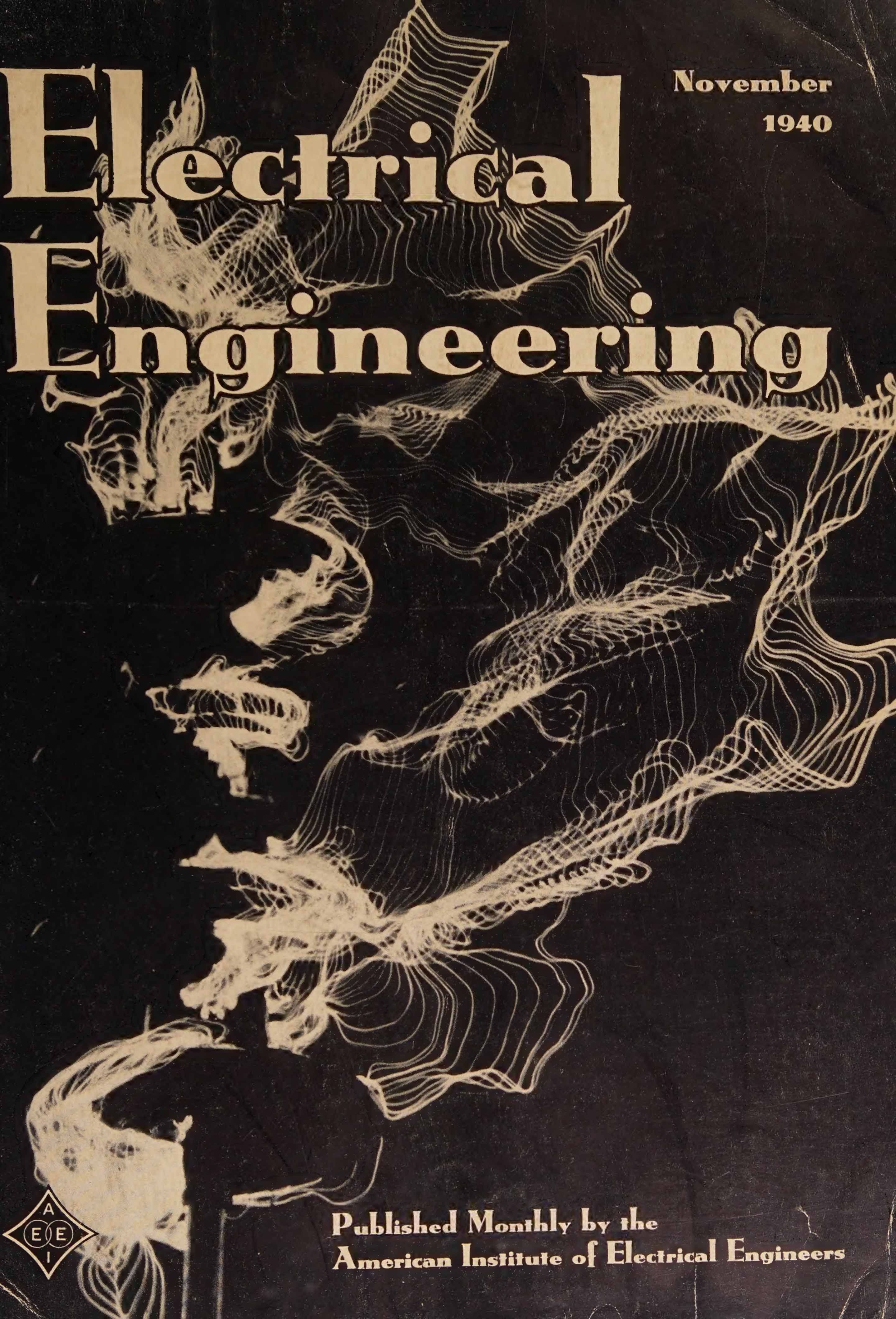
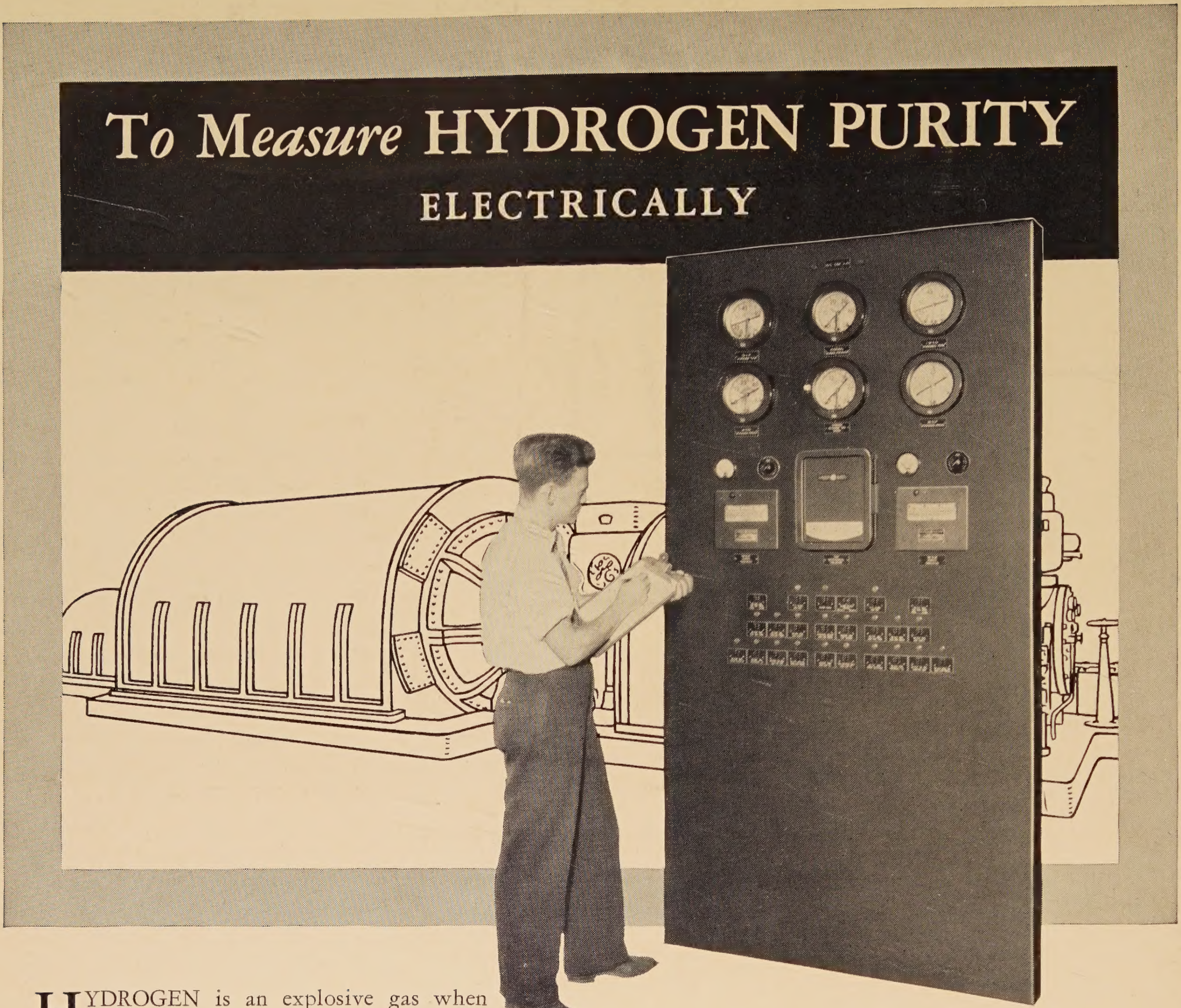
Electrical Engineering

November
1940



Published Monthly by the
American Institute of Electrical Engineers

To Measure HYDROGEN PURITY
ELECTRICALLY



HYDROGEN is an explosive gas when mixed with excess quantities of oxygen. Therefore, when filling hydrogen-cooled turbine-generators, converters, and condensers, it is necessary to know the hydrogen concentration at all times.

To fill the casing, carbon dioxide is pumped in, and air is let out until the percentage of carbon dioxide in air is about 70 per cent. Hydrogen is then admitted until the percentage of hydrogen in carbon dioxide is about 97 per cent. A somewhat similar reverse procedure is used to empty the casing.

This operation requires a means of measuring the various gas mixtures in order to prevent the formation of an explosive mixture. The changing analysis of the gas must be known throughout the operation, and particularly at the changeover points, so that safety of the procedure is assured. This requires an indicating instrument, for chemical analysis is too slow, as well as too expensive.

An electric instrument, operating on the thermal-conductivity principle, was developed by G-E engineers for this purpose. In addition to giving a continuous analysis, it indicates the purity of the hydrogen after the casing is filled, and while the machine is in operation. By means of an alarm system, it gives both visible and audible warnings, should the hydrogen mixture drop below a predetermined percentage.

In addition to building instruments for special measurement problems, G.E. offers a complete line of standard instruments for the measurement of any electrical quantity—current, voltage, resistance, watts—in styles and ratings to fill every need. When you have a problem that involves measurement, let us help you solve it. General Electric Company, Schenectady, N. Y.

HEADQUARTERS FOR ELECTRICAL MEASUREMENT

GENERAL ELECTRIC

602 14

Electrical Engineering

Registered U. S. Patent Office

for November 1940—

The Cover: A standard 60-cycle AIEE wet flashover test on a six-unit string of suspension insulators, as seen by the camera.

Photo courtesy Ohio Brass Company

Electrons Extend the Range ...V. K. Zworykin ...441

Trends in High-Intensity Mercury Lamps ...George A. Freeman ...444

High-Speed Motion Pictures Aid Design ...J. R. Townsend ...448

Ceramic Insulating Materials ...Hans Thurnauer ...451

Frequency-Selective Feedback for Audio Systems ...W. N. Brown, Jr., E. W. Sheridan...460

An Electronic Relay for Initiating Vapor Discharges ...Edward C. Dench ...461

A Graphical Solution of Transient Stability ...H. H. Skilling, M. H. Yamakawa ...462

Miscellaneous Short Item: Faults in Three-Phase Systems, 443

Institute Activities ...466

Of Current Interest ...475

Transactions Section *(Follows EE page 482; a preprint of pages 603–642 of the 1940 volume)*

Transient Starting Torques in Induction Motors ...A. M. Wahl, L. A. Kilgore ...603

A High-Speed Differential Relay for Generator Protection ...W. K. Sonnemann ...608

Frequency Modulation ...W. L. Everitt ...613

Low-Voltage D-C Measurements on Electrical Insulating Oils ...J. L. Oncley, W. C. Hollibaugh ...625

Rapid-Recording A-C Bridge ...W. Mikelson, H. W. Bousman ...628

Effect of Load Factor on Operation of Power Transformers ...V. M. Montsinger ...632

Dead Points in Squirrel-Cage Motors ...Quentin Graham ...637

©

VOLUME 59 NUMBER 11

Published Monthly by the

American Institute of Electrical Engineers

(Founded 1884)

ROYAL W. SORENSEN, President H. H. HENLINE, National Secretary

—PUBLICATION COMMITTEE—

D. M. Simmons, *chairman* J. W. Barker O. W. Eshbach H. H. Henline H. W. Hitchcock S. H. Mortensen A. G. Oehler H. S. Phelps H. H. Race S. P. Shackleton M. W. Smith I. Melville Stein S. B. Williams

—PUBLICATION STAFF—

G. Ross Henninger, Editor
Floyd A. Lewis, Associate Editor
F. A. Norris, Business Manager
C. A. Graef, Advertising Manager

Entered as second class matter at the Post Office, Easton, Pa., April 20, 1932, under the Act of Congress March 3, 1879. Accepted for mailing at special postage rates provided for in Section 538, P. L. & R. Act of February 28, 1925. ¶ Publication Office: 20th & Northampton Streets, Easton, Pa. Editorial and Advertising Offices at the headquarters of the Institute, 33 West 39th Street, New York

¶ Statements and opinions given in articles and papers appearing in "Electrical Engineering" are the expressions of contributors, for which the Institute assumes no responsibility.

¶ Correspondence is invited on all controversial matters.

High Lights • •

Branch Prize Papers. The AIEE national prize for Branch paper, for student papers presented during the year ending June 30, 1939, was awarded jointly to authors of two papers, and was presented to the recipients at the Institute's 1940 summer convention; abstracts of both papers appear in this issue. One paper describes a new electronic relay for initiating arc discharges in gases, which was developed primarily for starting low-voltage fluorescent lamps and is already being used commercially for that purpose (*page 461*). The other paper describes a method of improving the acoustical response of an audio-frequency sound system by frequency-selective feedback (*pages 460–1*).

Frequency Modulation. Radio communication is made possible by varying one of the characteristics of a high-frequency electromagnetic wave in accordance with the instantaneous variations of the signal to be transmitted; this process is known as modulation. Variation of the amplitude of the wave has been the accepted method, but frequency modulation, in which the amplitude remains constant and the frequency varies, offers unique advantages and may produce a marked change in broadcasting in the next few years (*Transactions pages 613–25*).

High-Intensity Mercury Lamps. As early as 1906, the characteristics of the mercury arc under pressures higher than atmospheric pressure were investigated. Commercial development of practical high-intensity mercury-arc lamps operating at high pressures was delayed, however, because suitable materials for manufacturing practical lamps were lacking. New materials developed in recent years now have brought these lamps out of the laboratory, and further developments are expected to extend their applications (*pages 444–7*).

Ceramic Insulation. Defined as "materials that are inorganic and brought to permanent shape and hardness by high temperatures," ceramic materials occupy an almost indispensable position in electrical apparatus and circuits. An authority on the subject reviews in this issue the various types of ceramic materials used for electrical insulation, the raw materials used in their manufacture, methods of manufacture, and characteristics and applications of the finished products (*pages 451–9*).

High-Speed Motion Pictures. In order correctly to design apparatus to meet the demands of the modern age, involving high power, high speed, and complicated mechanical movement, it is necessary to be able to analyze mechanical motion with great precision. High-speed motion pictures have proved their value for this purpose; a camera recently developed, using a continuously moving film, is capable of taking pictures at a rate of 4,000 per second (*pages 448–50*).

Differential Relay. High-speed differential relaying for generator protection is complicated by the presence of the d-c transient in asymmetrical through fault currents, which produces a false differential current because of dissimilar performance of the current transformers. Means have been provided in a new relay to discriminate between false and true differential currents of tripping magnitude (*Transactions pages 608–12*).

Transient Stability. An extension of the graphical equal-area method of determining transient stability of power systems, applicable to systems that can be reduced to two equivalent machines, gives the angular position of the synchronous machine as a function of time, and thereby permits the general method of the equal-area solution to be applied to system disturbances in which time is a factor (*pages 462–5*).

Loading Transformers. Additional capacity may be obtained by the method of loading transformers by temperature, but consideration must be given to the effects of different shapes of system load factors on aging of insulation. Permissible peak loads will vary depending on ambient temperature and load factor, for which loading curves have been plotted (*Transactions pages 632–6*).

Electron Microscope. Having a resolution capability at least 20 times better than the theoretical limit of the ordinary microscope, the electron microscope in its present form provides the research worker with "an opportunity unparalleled since the original discovery of the compound microscope." Continued research is expected to lead to instruments of yet greater power and usefulness (*pages 441–3*).

Conductance of Insulating Oils. Apparatus has been developed for measuring at low voltages the d-c conductances of electrical-insulating oils. Measurements of the d-c conductance with time of a highly refined oil substantiate the theory that low voltage methods do measure the true d-c conductance of electrical insulating oils (*Transactions pages 625–8*).

Technical Conferences. Four technical conferences held at AIEE meetings are reported in this issue: two conferences on load swings, one held at the 1940 summer convention and one at the Pacific Coast convention (*pages 468–9*); and two conferences held at the recent Cincinnati meeting, one on motors and one on protective lighting (*pages 467–8*).

Induction-Motor Starting Torques. When starting an induction motor, transient alternating torques occur having the same frequency as that of the power supply. Analysis and tests show that for the first few cycles these torques may be several times the pull-out torque (*Transactions pages 603–07*).

Dead Points. Certain squirrel-cage motors may have a wide variation in starting torque depending on the angular position of the rotor. A new analysis, confirmed by test results, makes possible correlation of many apparently divergent results and avoidance of troublesome combinations in design (*Transactions pages 637–42*).

A-C Bridge. A new rapid automatic recording a-c bridge continuously records the power factor and capacitance during life runs or short-time tests on cables, capacitors, and insulating materials at a frequency of 60 cycles per second (*Transactions pages 628–31*).

Cincinnati Meeting. With a registered attendance of 599, the AIEE Middle Eastern District meeting recently concluded at Cincinnati, Ohio, established a new attendance record for that District (*pages 466–7*).

Publication Procedure. Some of the changes in publication procedure brought about by the recently adopted changes in AIEE publication policy are explained in this issue (*page 469*).

Coming Soon. Among special articles and technical papers currently in preparation for early publication are: an article on modern network radiobroadcasting by C. A. Rackey; an article reporting experimental data on electric shock by C. F. Dalziel (M'39); an article on the use of infrared lamps for industrial heating purposes by P. H. Goodell (A'40); an article outlining how the instrument landing of aircraft is accomplished; a paper on reference values for temperature, pressure, and humidity by P. L. Bellaschi (F'40) and P. H. McAuley (A'36); a paper on rating of potential devices and suggested material for a standard by J. E. Clem (F'38) and P. O. Langguth (A'28); a paper describing a new high-speed thermal wattmeter by J. H. Miller (M'26); a paper describing a method for detecting the ionization point on electrical apparatus by G. E. Quinn (M'33); a paper on computation of accuracy of current transformers by A. T. Sinks (A'36); a paper on the dielectric strength and life of impregnated-paper insulation by J. B. Whitehead (F'12); two papers on a decade of progress in electronics in the field of communication and in fields other than communication by S. B. Ingram (M'38) and W. C. White (M'30); a paper on an oilless circuit interrupter using water by W. M. Leeds (M'38); and a paper describing measurements at radio frequencies by H. R. Meahl (A'37), P. C. Michel, M. W. Scheldorf (A'38), and T. M. Dickinson.

Subscriptions—$12 per year to United States, Mexico, Cuba, Porto Rico, Hawaii, Philippine Islands, Central and South America, Haiti, Spain, Spanish Colonies; $13 to Canada; $14 elsewhere. Single copy $1.50. ¶Address changes must be received by the 15th of the month to be effective with the succeeding issue. Copies undelivered because of incorrect address cannot be replaced without charge. ¶Electrical Engineering is indexed annually by the Institute, weekly and monthly by *Engineering Index*, and monthly by *Industrial Arts Index;* abstracted monthly by *Science Abstracts* (London). Copyright 1940 by the American Institute of Electrical Engineers. Printed in the United States of America.

Number of copies this issue 23,500

Electrons Extend the Range

V. K. ZWORYKIN
MEMBER AIEE

The recently developed electron microscope has a resolution capability at least 20 times greater than that of the ordinary microscope, and research aimed at extending its range is still in progress. The importance of this new tool to biology and medicine would be hard to overestimate; industry also expects to find many uses for it.

"SEEING is believing," an old adage tells us and indeed man owes his knowledge of the world about him primarily to his sense of sight. Shape, brightness, color—these suffice to identify most familiar objects. Yet, however marvelous an instrument the human eye may be, its ability to recognize and differentiate is limited. Two objects so close together that their images are projected by the lens of the eye on the same sensitive nerve cell of the retina cannot possibly be told apart. Thus, a set of half-tone dots or shading lines separated by less than 1/100 inch appears to the average eye as a uniform gray surface without structure—the dots or lines of the object are not "resolved" by the eye, whose "limit of resolution" lies in the neighborhood of 1/100 inch.

To make it possible for the eye to resolve finer details in an object, it is necessary to project a larger image thereof on the retina than can be formed by the lens of the eye by itself. This may be accomplished by placing a convex lens between the object and the eye. If still higher resolution is demanded, the simple magnifier must be replaced by a compound microscope. Here a first lens, the objective, produces a greatly enlarged image of the object, which image is then viewed with the aid of a suitable magnifier, the eyepiece. As an alternative, the eyepiece may act as a projection lens and record the image observed on a photographic plate.

The discovery of the compound microscope by Leeuwenhoek during the latter part of the 17th century opened up a whole new world to the scientifically curious. From the primitive life of the ponds to the cell structures of the higher plants and animals, nature had to yield up more and more of her secrets as, in the past three centuries, this powerful instrument was improved and perfected. But with this perfection came the recognition of a barrier which could not be surmounted. Light, the medium producing the enlarged image, could not resolve details appreciably smaller than its own wave length. As the latter is of the order of 2/100,000 inch, it followed that structures less than about 1/100,000 inch apart could not be separated; increasing the magnification beyond 1,000 or 2,000 diameters yielded a larger but not more informative picture. All details simply appeared progressively more blurred.

The obvious remedy for this limitation of the microscope was the use of a finer-grained medium, having shorter wave lengths. Thus, in some instruments, ultraviolet radiation has replaced visible light. However, only a relatively small improvement, by a factor of the order of two, could be thus obtained, as the far ultraviolet is too readily absorbed by the lenses to be applicable. X rays, also, do not lend themselves to this task because of the difficulty of refracting and reflecting them. Thus, for a number of decades, it appeared as though, to all intents and purposes, the ultimate limit in the direct observation of minute objects had been reached.

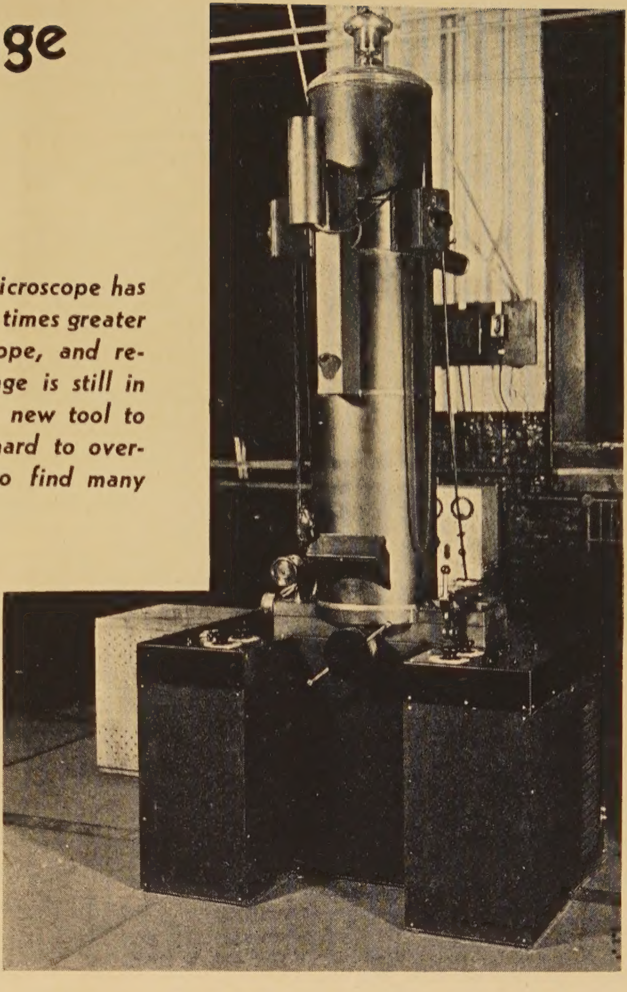
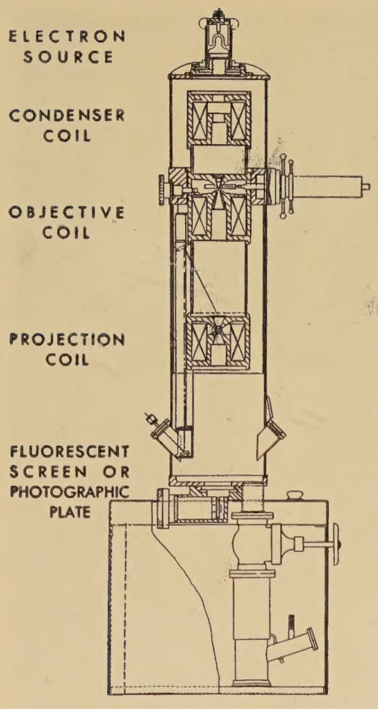


Figure 1. The RCA electron microscope

The situation was changed radically with the advent of the electron microscope. In 1924 the French physicist Louis de Broglie had indicated that a stream of electrons should have wave properties similar to those of a beam of hard X rays, the wave length being inversely proportional to the electron velocity. For electrons having a velocity corresponding to 30 to 100 kv, this wave length is approximately 1/100,000 of the wave length of visible light. Two years later Heinrich Busch of Darmstadt showed that an axially symmetric electric and magnetic field acted on electron beams just as a lens acted on light beams, bending the paths of the electrons toward or away from the axis. Thus, with the aid of a solenoid or a pair of coaxial apertures at different potentials, an electron source could be imaged sharply on a fluorescent screen or photographic plate.

V. K. ZWORYKIN is associate director, research laboratories, RCA Manufacturing Company, Camden, N. J.



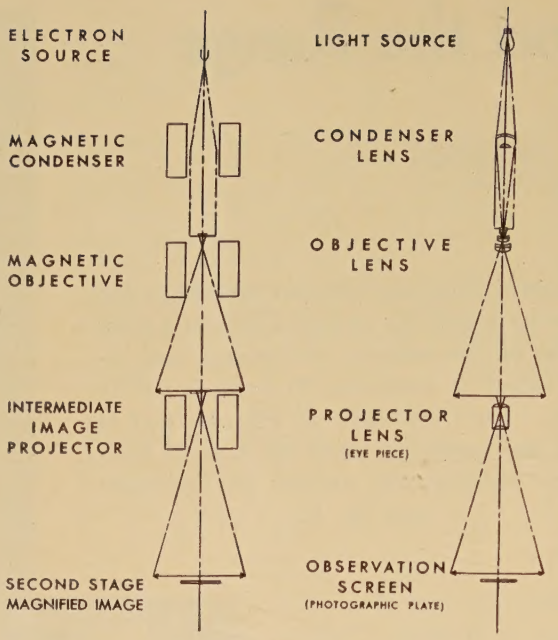


Figure 2. Schematic sketch of microscope and ray paths

Simplified sketch (left) of the electron microscope developed in the RCA laboratories at Camden, N. J. Diagram in center shows how closely the operation of the electron microscope is analogous to that of the conventional light microscope (right). Suitably shaped magnetic fields take the place of glass lenses. A beam of electrons traveling at high velocity (at voltages of from 30 to 100 kv) takes the place of ordinary light. The electron rays are converged by condenser lens onto the specimen. After passing through the specimen, the objective lens coil forms a first image, enlarged about 100 times. The projection lens coil then magnifies the image again about 250 times, making an over-all magnification of 25,000. The final enlarged image can be viewed directly by causing it to strike a fluorescent screen which makes it visible, or it can be made to record the image on a photographic plate for permanent record. The final photograph can be usefully magnified by photographic enlargement up to 100,000 diameters.

Herewith the essential conditions for the creation of an instrument with a resolving power exceeding that of the light microscope by a large factor were fulfilled. However, much further research was required before such apparatus could actually be realized. In this development, particularly that part relating to the production and guiding of the electron beams, the experience gained in the development of earlier electronic devices, such as cathode-ray oscillograph tubes and electronic television tubes, proved of the greatest value. The problem is complicated by the fact that electrons, unlike light, are readily absorbed by any material substance. This requires the evacuation of the interior of the electron microscope and the use of exceedingly thin object supports and specimens. The development of a technique of preparing and mounting biological specimens for examination with electrons was first undertaken by Doctor Ladislaus Marton at the University of Brussels.

In view of their wide experience in connection with electronics and television, it was natural that the RCA laboratories should undertake the development of an electron microscope suitable for research purposes. This work has resulted in the instrument shown in figure 1 and in section in figure 2, designed by Doctor Marton with the co-operation of other staff members. A comparison of the schematic drawings of ray paths in the electron microscope and in a light microscope shows that the operation of the two instruments is essentially similar. The differences are

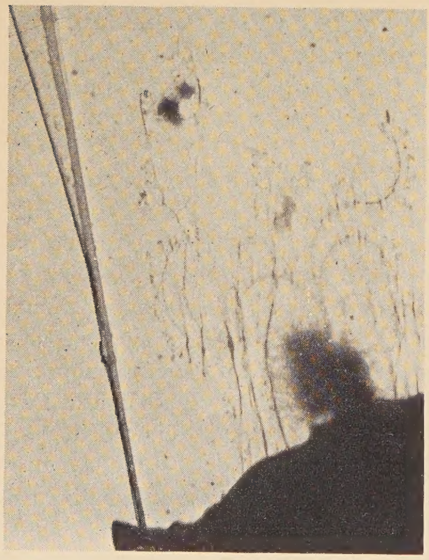


Figure 3. Typhoid bacillus, magnified 10,000 times

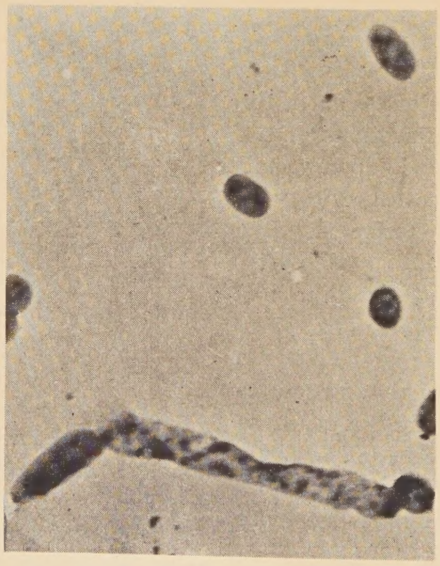


Figure 4. Culture of whooping-cough bacteria, magnified 9,000 times

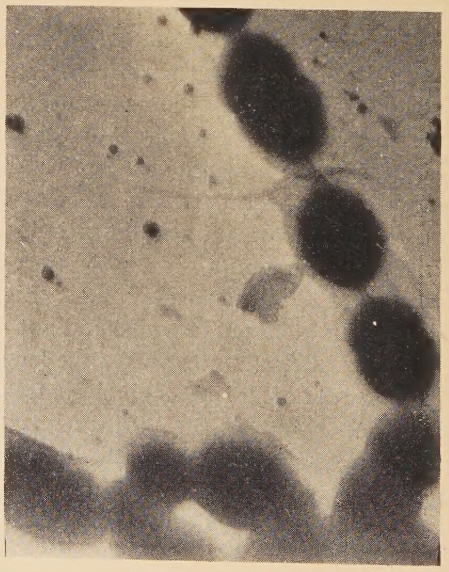


Figure 5. Culture of streptococcus bacteria, magnified 20,000 times

dictated primarily by the differences in the properties of electrons and of light. Electrons leaving the source, a hot tungsten filament, are accelerated to their top speed by the strong electric field between the filament (at a negative potential of 30 to 100 kv) and the anode (at ground potential) placed directly below it. The electron beam issuing from a fine hole in the anode is concentrated on the object by a magnetic condenser lens. Electrons passing through the object and an aperture in the magnetic objective are focused by the latter into an image of the object magnified approximately 100 times and situated just above the magnetic projector lens. This last lens selects a portion of the intermediate image and enlarges it by a factor of approximately 250, yielding a final image projected on an interchangeable fluorescent screen or photographic plate with a magnification of about 25,000. Each of the three lenses consists of a coil of magnet wire enclosed in a soft iron shield so shaped as to concentrate the magnetic field on a short section of the axis of the microscope.

The final image can be observed on the fluorescent screen through vacuum-tight windows in the side of the microscope. A simple periscope arrangement permits the observation of the less highly magnified intermediate image at the same eyelevel, facilitating the selection of the portion of the object to be further magnified. In order to make possible the rapid exchange of objects and photographic plates in spite of the high vacuum existing in the microscope, air locks are provided, similar to the escape chambers of a submarine. For example, when the object has been shifted by an external manipulation to its escape chamber, the latter can be closed off from the rest of the microscope, air can be admitted, and the object exchanged. After the chamber has been pumped out once more, the specimen can be reintroduced into the microscope—an operation that altogether takes only a little more than a minute.

The objects to be examined are deposited on nitrocellulose foils less than 1/1,000,000 of an inch thick. They may be cultures of bacteria, virus filtrates, colloidal suspensions, dusts or smokes, or materials of yet other character. The electron pictures shown in figures 3 to 6, taken by Doctor Marton, give an indication of the possibilities of the instrument. The first shows a typhoid bacillus with its long curved flagella—first revealed in their natural form by the electron microscope. The next picture shows a culture of whooping-cough bacteria, some of the bacteria shown being apparently in various stages of cell division. The large amount of detail visible within the bacteria is particularly worthy of note. Figure 5 reproduces a streptococcus culture. The final picture, figure 6, shows an application of the new microscope to the study of material so finely divided that the light microscope is no longer able to reveal the jagged contours of the individual particles.

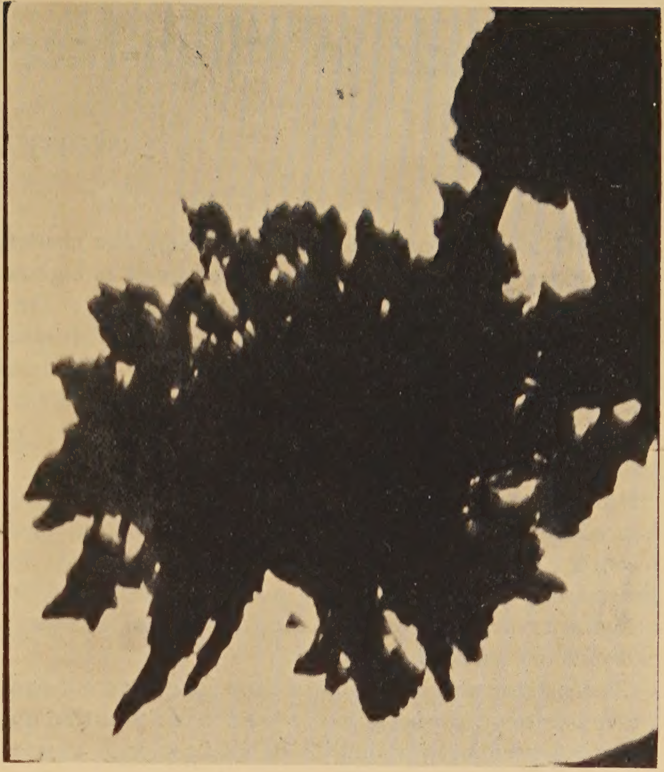


Figure 6. Iron oxide powder (rouge), magnified 15,000 times

A careful examination of pictures such as these shows that the electron microscope has, at the present time, a resolution capability at least 20 times better than the theoretical limit of the ordinary microscope—that is, it can separate objects less than 1/50 of a wave length of visible light or 1/3,000,000 inch apart. Certain fundamental defects of electron lenses, which it has not proved possible to overcome with the means and knowledge now at hand, have so far prevented greatly exceeding this resolution. However, active research in this direction is being carried on and there is every reason to believe that it will lead, in the due course of events, to instruments of yet greater power and usefulness. In the mean time, one thing is certain: The electron microscope in its present form provides the research worker with an opportunity unparalleled since the original discovery of the compound microscope by Leeuwenhoek.

Faults in Three-Phase Systems

A PAPER published in the April 1940 issue of the *Bell System Technical Journal*, pages 290–305, presents "A Solution for Faults at Two Locations in Three-Phase Power Systems" and is an outgrowth of studies of double faults to ground in three-phase power systems made by the author, E. F. Vaage (M'39), of the Bell Telephone Laboratories, in connection with work of the Joint Subcommittee on Development and Research, Edison Electric Institute and Bell Telephone System. The paper provides a systematic solution, based upon the method of symmetrical components, by means of which currents and voltages can be determined at times of fault involving any combination of phases at one or two locations on three-phase power systems in which generators may be assumed to be in phase and of the same internal voltage, and where load currents may be neglected.

Trends in High-Intensity Mercury Lamps

GEORGE A. FREEMAN

Although the characteristics of the mercury arc at pressures as high as two atmospheres were investigated more than 30 years ago, lack of suitable materials delayed until recent years the commercial development of practical high-pressure high-intensity mercury-arc lamps.

IN THE decade past, effort in the search for higher-efficiency light sources has been gradually shifting from incandescent-filament lamps to gaseous-discharge lamps. The activity has brought into public use high-intensity mercury lamps for industrial and flood lighting, sodium lamps for highway illumination, and more recently the low-pressure-arc fluorescent lamps for general use. There have been a number of related developments as, for example, the bactericidal Sterilamp and mercury sun lamps.

The fundamental principles of these lamps are not new. There is often a period of many years from scientific discovery to practical use, and so it has been with gaseous discharges. The Cooper Hewitt type of mercury lamp which appeared about 1905 suffered almost no competition from other discharge lamps until the high-intensity mercury lamp had its commercial introduction in the United States in 1934. From a scientific point of view the high-intensity mercury arc was nearly as old as the Cooper Hewitt low-pressure arc. Kuch and Retchinsky in 1906 reported the improved spectral output and high luminous efficiency of mercury arcs at mercury pressures as high as two atmospheres. The 28-year delay in making commercial use of this discovery was due in large part to the lack of materials to make practical lamps. The development of a glass having a softening point of approximately 925 degrees centigrade, and oxide-coated tungsten electrodes for use on alternating current, were the principal factors in giving the high-intensity mercury lamp long life and simplicity.

Similarly, sodium-vapor lamps began their commercial existence in 1932 after a suitable alkali-resistant glass had been developed to resist the corrosive effect of active sodium vapor on the glass envelope. Fluorescent lamps, appearing in 1938, followed the development of efficient fluorescent materials in all colors and suitable starting devices that eliminated the need of high voltage.

The efficiency of a tungsten-filament lamp is definitely limited by the melting point and rate of evaporation of tungsten. Improvements will yet be gained by changing the gas filling to retard tungsten evaporation and by special coiling of the tungsten wire to conserve heat, but at best the gains probably will be slight. Discharge lamps, however, are already two or three times as efficient as tungsten-filament lamps, and their possibilities are not nearly so well explored. The efficiencies of several representative light sources are shown in table I.

Since other workers have already described the development of sodium lamps,[1,2] high-intensity glass mercury lamps,[3–5] and fluorescent lamps[6,8] in some detail, it is the purpose here to trace the development of high-intensity mercury lamps in quartz.

From the Cooper Hewitt low-pressure mercury lamp to the type *A-H*1 high-intensity lamp operating with one atmosphere mercury pressure, the gains were increased efficiency, improved color, and more compact design. In furthering these gains, still higher mercury pressures were tried. This meant greater concentration of the arc, resulting in higher heat dissipation per inch of arc length and consequent overtaxing of the materials used in the lamp. The glass envelope was softened by the higher temperature in lamps operating with mercury pressures higher than one atmosphere. Fused quartz was taken as the best material to replace it.

Commercial use of fused quartz, while making possible still more efficient mercury lamps, at the same time presents a new series of problems. Fused quartz of sufficient purity was expensive to manufacture and to use because of its high melting point and low coefficient of thermal expansion. Table II compares these properties with those of other materials. While relatively inert at ordinary temperatures, fused quartz combines readily with alkaline materials at temperatures of 600 degrees centigrade and higher. The use of barium and strontium oxides as the electron-emissive coating in high-pressure quartz lamps therefore was soon found to be poor practice. The extreme conditions imposed upon an electrode by a high-pressure arc sputtered or vaporized the coating over to the quartz envelope. Barium silicate would form, appearing as frosting or crystallization on the quartz inner wall. The sputtering of the electrode must be minimized also

Table I. Efficiencies of Representative Light Sources

Source	Lumens Per Watt
Tungsten 100-watt	16
Tungsten 1,000-watt photoflood (short life)	33
Sodium 10,000-lumen	55*
Daylight fluorescent 30-watt	37*
Green fluorescent 30-watt	75*
Mercury 100-watt type *A-H*4 quartz	35*
Mercury 1,000-watt type *A-H*6 water-cooled quartz	65*
Mercury 400-watt type *A-H*1 glass	40*
Low-pressure mercury Cooper Hewitt	15 to 19

* Efficiency shown is of the lamp proper; over-all efficiency of the lamp and auxiliary equipment is slightly lower.

George A. Freeman is vapor lamp engineer, lamp division, Westinghouse Electric and Manufacturing Company, Bloomfield, N. J.

Table II. Comparison of the Properties of Quartz With Those of Other Materials

Material	Thermal Coefficient*	Softening Point (Degrees Centigrade)	Strain Point (Degrees Centigrade)
Pure quartz	5.5×10^{-7}	1,667	1,070
96 per cent quartz	7.8	1,442	857
Hard glass for *A-H*1 mercury lamps	39	925	679
Pyrex	33	819	510
Nonex	36	756	494
Soft lead glass	87	630	395
Special quartz to tungsten sealing glass	14	1,200	
Tungsten	43	3,370	
Molybdenum	49	2,620	

* Coefficient given is the increase in length per unit length per degree centigrade.

because of the smaller size of the quartz bulb which will darken from sputtered particles sooner than the larger glass bulb that would be used for the same wattage rating. All these problems had to be solved to make practical lamps.

QUARTZ SEALS

A wire of tungsten or of any other metal cannot be sealed directly into quartz to form a gastight seal over a wide range of temperature. As the seal cools after being made, the wire shrinks away from the quartz, which has a lower coefficient of expansion, and leakage results. In low-pressure discharge devices where quartz has been used, seals are made between quartz and metal wires by separating them with several intermediate steps of glasses having graded expansion properties. While satisfactory in many applications, such graded seals have three unsatisfactory features when used in high-pressure mercury lamps. First, their size is necessarily so large as to make large cavities in the arc chamber remote from the arc; second, the softening points of the higher-expansion-coefficient glasses nearest the seal wire are too low for the high concentration of energy; and third, their manufacturing cost is excessive for making economical lamps in quantity.

Any cavity away from the arc may not receive sufficient heat from the arc to vaporize all the mercury, or at least tends to slow up the vaporization and prolong the warming-up period after a lamp is turned on. Typical warming-up characteristics are shown in figure 1 for the 250-watt quartz lamp type *A-H*5. The time for all the mercury to vaporize and maximum light output to be obtained is four or five minutes. A cavity remote from the arc would prolong this time or perhaps prevent normal operation.

The development of a new glass having such properties as to make a single-step quartz-tungsten seal possible has been most important in bringing high-pressure quartz lamps out of the laboratory. The new glass has a high softening point of 1,200 degrees centigrade and a coefficient of thermal expansion of 14×10^{-7}, between those of quartz and tungsten, and the strength to withstand the severe strains in joining these quite different materials. Care is taken in designing the seals to minimize strain by avoiding massive beads or thick regions of glass. Such a design as a press seal used in most lamps and vacuum tubes would not be practical for quartz seals because the strains would be excessive. Figure 2 shows the seal design of the 100-watt lamp.

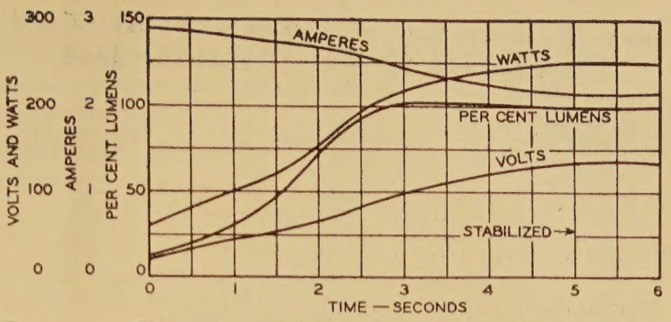


Figure 1. Chart showing heating-up characteristics of type A-H5 250-watt mercury lamp

THORIUM ELECTRODES

The electrode problem has been solved by using non-activated electrodes containing a metal having high electron-emissive properties, such as thorium. Thorium is more refractory than barium and strontium-oxide coatings, and is therefore better able to provide long life in a high-pressure discharge lamp. With arc-heated thorium electrodes, the arc can be initiated when the electrodes are cold with alternating voltages as low as 130 volts. Thorium metal is inert with respect to quartz and does not require any processing to become electron-emissive. It is desirable that pure thorium be used. One simplified electrode design consists of a piece of thorium sheet or wire inside a tungsten helix as illustrated in figure 2. The seal wire also passes inside the helix and all three parts are clamped or spot-welded together. The thorium core is positioned slightly back from the free end of the tungsten helix in order to maintain the temperature of the thorium below the fusion point.

Averaged data in table III compares the thorium elec-

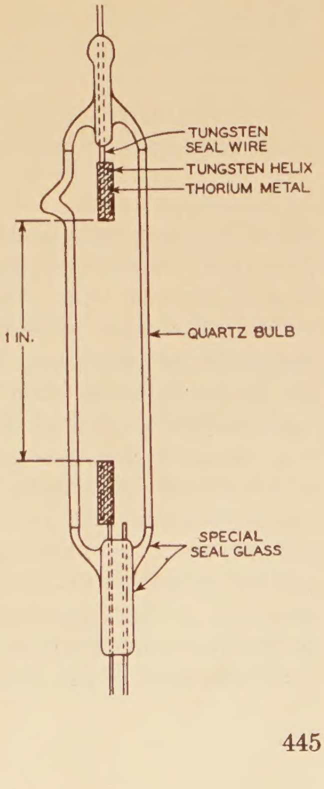


Figure 2. Diagram of quartz inner bulb for 100-watt type A-H4 mercury lamp

Table III. Comparison of Thorium and Oxide-Coated Electrodes in the 100-Watt A-H4 Mercury Lamp

Hours*	Lumens—Thorium Electrodes	Lumens—Oxide Electrodes
0	3,610	3,450
100	3,260	3,180
500	3,090	2,680
1,000	3,030	2,320
2,000	2,620	1,430

* These results are averaged on lamps turned on five hours and off one hour to approximate actual operating conditions in ordinary service.

trode with the former oxide-coated electrode in the 100-watt type *A-H*4 quartz mercury lamp. These data were taken with lamps being tested on a burning schedule of five hours on and one hour off to approximate normal burning conditions. The advantage in using thorium becomes more obvious the longer the lamps are burned. The inherent life of thorium electrodes is very long. One instance of a lamp still operating satisfactorily after 16,000 hours seems to indicate that something other than electrode failure will determine the life of quartz lamps.

QUARTZ BULBS

The cost of fused quartz is another problem now in process of being solved. Large-scale use of it will be a partial solution in itself. There is promise of a low-cost substitute in the recently publicized "shrunk glass"[7] which is 96 per cent quartz and has approximately the properties of pure fused quartz. This glass is prepared in a rather unusual way. The desired shape is blown in a mold with a glass of somewhat normal characteristics having low melting point. By a special process practically all the constituents other than silica are removed. A high-temperature firing follows to consolidate the remaining silica. In this latter operation the shrinkage of the article corresponds roughly to that taking place in the firing of porcelain. The process is a radical departure from any other method of making fused quartz. It has the important advantage that abundant domestic raw materials are used. Other processes require quartz crystals imported from remote regions of Brazil.

Table IV. Characteristics of High-Intensity Mercury Lamps

Lamp Type	Watts	Mercury Pressure (Atmospheres)	Lumens Per Watt	Maximum Brightness (Candles Per Sq Cm)	Guaranteed Life*
*A-H*1, glass	400	1.0	40	50	2,000
*A-H*2, glass	250	0.5	30	50	2,000
*A-H*3, quartz	85	25–30	35	900	500
*A-H*4, quartz	100	8–10	35	400	1,000
*A-H*4, quartz (black UV)	100	8–10			1,000
*S*4, quartz (sun lamp)	100	8–10	35	400	400
*A-H*5, quartz	250	4–5	40	300	1,000
*A-H*6, quartz (water-cooled)	1,000	75–80	65	30,000	75

* Hours, except figure for *S*4 lamp which indicates number of applications.

Already most of the important operations in manufacturing quartz lamps are being done with the aid of machines. The use of machines is eliminating the high cost that has been synonymous with quartz working for many years. Contrasted with mercury lamps, sodium-vapor lamps are still exhausted by "trolley" exhaust which is slower and more expensive. The more complicated design of sodium lamps does not lend itself readily to automatic operations.

TYPE H QUARTZ MERCURY LAMPS

In table IV the characteristics of type *H* high-intensity quartz mercury lamps are recorded. The 100-watt size is available with any of three outer bulbs, shown in figure 3, each intended for a different use. The type *A-H*4 for general lighting has a tubular Nonex bulb which transmits visible light but absorbs the strong ultraviolet radiation of the mercury arc. The *S*4 sun lamp with the same quartz arc tube employs a glass outer bulb that transmits not only the visible range of wave lengths of 8,000 to 4,000 angstroms, but also the ultraviolet rays down to 2,800 angstroms. This lamp has approximately the same ultraviolet output as the older *S*1 sun lamp, but consumes less than one-third the energy. The 100-watt *B-H*4 lamp for special decorative and other uses is an efficient source of what is popularly known as "black" light. Its red-purple bulb filters out the visible radiation, but transmits the strong 3,650-angstrom radiation. Certain materials, such as zinc sulphide and anthracene, when exposed to this wave length will fluoresce, emitting visible light of various colors. Such materials are used in paints that are to be floodlighted with "black" light to create attractive decorative effects.

For all three forms in which the 100-watt lamp is made, the high-pressure mercury arc is more efficient than a low-pressure arc. The radiation from a low-pressure mercury arc is largely the 2,537-angstrom resonant line. As the mercury pressure is increased this radiation is absorbed by the mercury vapor itself, and, instead, a larger proportion of the longer wave lengths is radiated. Hence the efficiency of visible and near-visible ultraviolet radiation is increased with increased mercury pressure.

The next larger lamp is the 250-watt type *A-H*5 lamp which besides general lighting is particularly suited to the

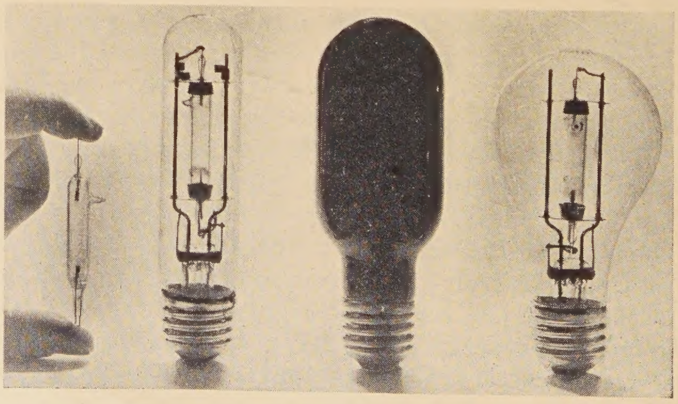


Figure 3. Three 100-watt quartz mercury lamps (left to right): quartz inner bulb, type A-H4, type B-H4, type S4

requirements of highway lighting (figure 4). Its small arc stream, which may be operated in a horizontal position, can be efficiently utilized with small inexpensive luminaires.

A 400-watt quartz lamp now being developed for general use may be compared with type *A-H*1 glass 400-watt lamp with which it will be interchangeable (figure 5). The efficiency is about 20 per cent higher, and because the arc in quartz is shorter and more concentrated, the utilization of the light produced may be higher. Angular or horizontal burning is made possible. The glass lamp is limited to vertical burning as the convection currents in the mercury vapor push the hot arc against the glass envelope and soften it when the lamp is burned in any other position. The convection currents are enough weaker in the smaller quartz bulb that the lamp may be operated in any position.

Both 250- and 400-watt quartz lamps have been extensively used in the New York World's Fair, the 250-watt lamp for floodlighting trees and the 400-watt lamp for the Lagoon of Nations fountain and the Perisphere.

The water-cooled 1,000-watt type *A-H*6 is the highest-pressure mercury lamp. Operating at 75 atmospheres mercury pressure, the arc has the highest brightness and efficiency of any mercury lamp now available. By concentrating 1,000 watts into a chamber an inch long and one-tenth inch in diameter, a 65,000-lumen light source is produced having a brightness of 30,000 candles per square centimeter or about one-fifth that of the sun. The quartz bulb, together with the water-cooling jacket, is smaller than the 250-watt air-cooled lamp, as can be seen in figure 4. Its uses have been mostly in special projection applications where high brightness is desired.

NEW APPLICATIONS

As to the future, it is expected that the high efficiency of these lamps will bring them to new fields. One example might be headlights on moving vehicles—automobiles, airplanes, and railway locomotives—where more light with minimum generator capacity is always to be desired. Another is in television or moving-picture-studio lighting where high levels of illumination are accompanied by intense heat radiation with low-efficiency light sources. The water-cooled mercury lamp is particularly suited to this service because the water acts as a filter, absorbing the long-wave infrared or heat radiation. The light is therefore much cooler than that obtained from incandescent lamps or carbon arcs.

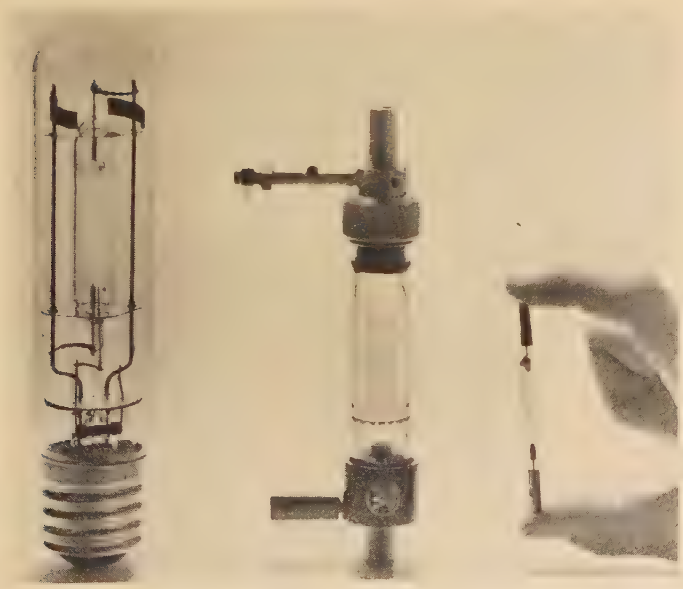


Figure 4. A 250-watt and a 1,000-watt quartz mercury lamp (left to right): 250-watt type A-H5, water-cooling jacket for A-H6, 1,000-watt type A-H6

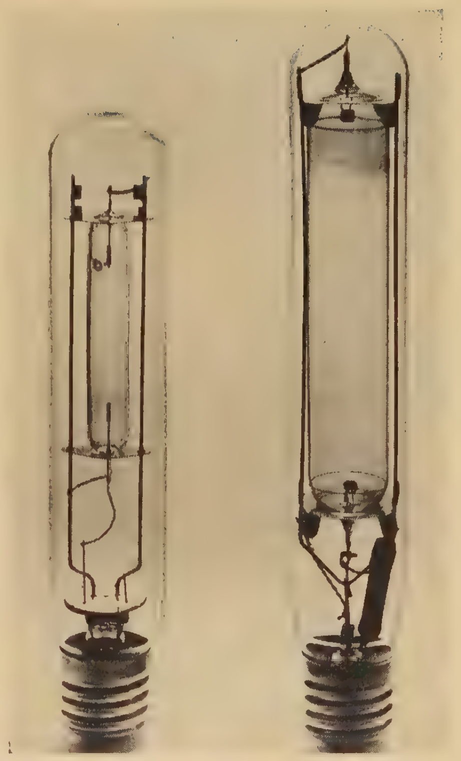


Figure 5. Two 400-watt mercury lamps (left to right): quartz lamp (under development); glass lamp type A-H1

For motion-picture projection, short high-current mercury arcs are being considered. For highway lighting, quartz high-intensity mercury lamps are widely used in Europe, and trial installations are being planned in the United States.

It is expected that greater general use of quartz mercury lamps will be brought about by inducements of lower cost resulting from better production methods and by longer life which is inherent but difficult to predict in discharge lamps as it has been found to be with vacuum tubes.

REFERENCES

1. The A-C Sodium-Vapor Lamp, G. R. Fonda and A. H. Young. *General Electric Review*, volume 37, 1934, pages 331–7.

2. Operating Characteristics of Sodium-Vapor Lamps, N. T. Gordon. *General Electric Review*, volume 37, 1934, pages 338–41.

3. High-Efficiency Gaseous-Conduction Lamps, L. J. Buttolph. Electrical Engineering (AIEE Transactions), volume 55, 1936, pages 1174–80.

4. High-Intensity Mercury-Arc Lamps, J. W. Marden, N. C. Beese, and G. Meister. Electrical Engineering (AIEE Transactions), volume 55, 1936, pages 1186–90.

5. High-Efficiency Mercury and Sodium-Vapor Lamps, L. J. Buttolph. *Journal* Optical Society of America, volume 29, March 1939, pages 124–30.

6. Low-Voltage Fluorescent Lamps, G. E. Inman and R. N. Thayer. AIEE Transactions, volume 57, 1938, pages 723–6.

7. Heat-Resisting Glass, *Chemical and Metallurgical Engineering*, volume 46, July 1939, page 444; and *Glass Industry*, volume 20, July 1939, page 269.

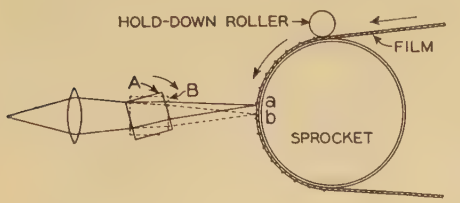
8. Fluorescent Lighting After Two Years, O. P. Cleaver. Electrical Engineering, volume 59, July 1940, pages 261–6.

High-Speed Motion Pictures Aid Design

J. R. TOWNSEND

The high-speed motion picture camera is a useful tool in studying rapid motion and has assisted in improving the design of electromechanical apparatus

THE early history of engineering was concerned largely with static mechanics, but the modern age has become concerned with high power, speed, and complicated mechanical movements much too rapid to be seen directly. This trend has become of increasing importance in the Bell System, with the development and improvement in speed and accuracy of machine-switching apparatus. In order correctly to design the necessary electromechanical apparatus to fulfill these requirements, it is necessary to be able to analyze mechanical motion with great precision.



Film moves continuously; light from object passes through cubical prism *AB* before reaching film, which keeps the image stationary on the film by refraction; when the prism moves from *A* to *B*, the image moves from *a* to *b*

Figure 1. Diagram illustrating principle of operation of camera

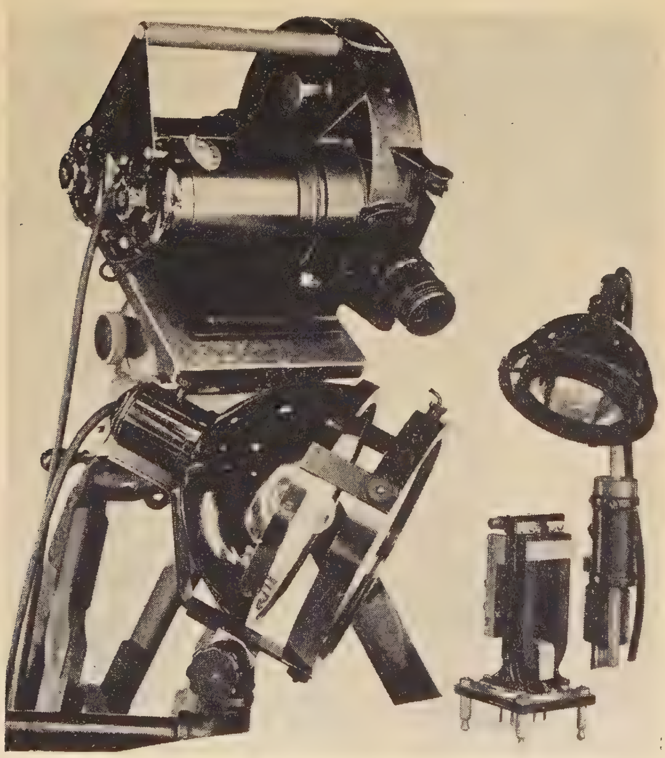


Figure 2. High-speed motion picture camera and lighting equipment

There are a number of available tools for the analysis of mechanical motion. If the motion is within the range of our sense of perception it may be followed by eye and the position of a point in terms of time may be plotted by direct measurement. If the motion is too rapid to be followed by eye and is repetitive it may be analyzed by means of a stroboscope. There are various forms of this device; they consist principally in using an intermittent shutter or flashlight which bears a definite phase relationship with the motion under investigation. It is also possible to use this flashing light, if it is intense enough and its duration short enough, to photograph successive positions of a moving object. This will give a series of still pictures from which the motion may be plotted and analyzed. This is precisely the method used by Professor Harold E. Edgerton (A'27, M'32) at Massachusetts Institute of Technology in taking instantaneous pictures of many familiar actions that are beyond our sense of perception, such as the beat of a fly's wings, the details of the breaking of an egg, and many other subjects which are presented in his book "Flash". The same device is used by him to make high-speed motion pictures. Here the film is driven continuously through a camera and the flashing light is of such short duration that a series of images is photographed without blurring on the moving film.

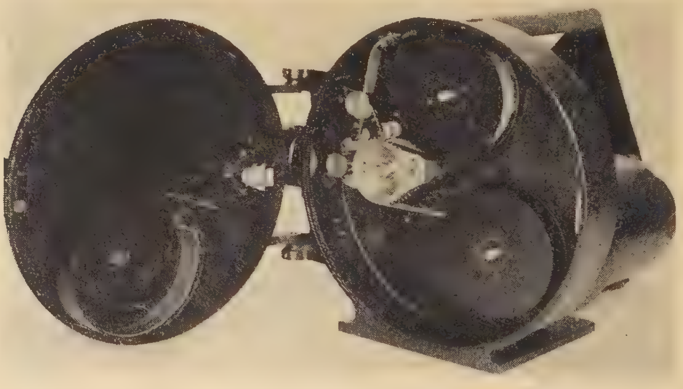


Figure 3. Interior of camera

Another method of obtaining a series of pictures of motion applicable to relatively slow movements is by means

---

J. R. Townsend is materials standards engineer, Bell Telephone Laboratories, New York, N. Y.

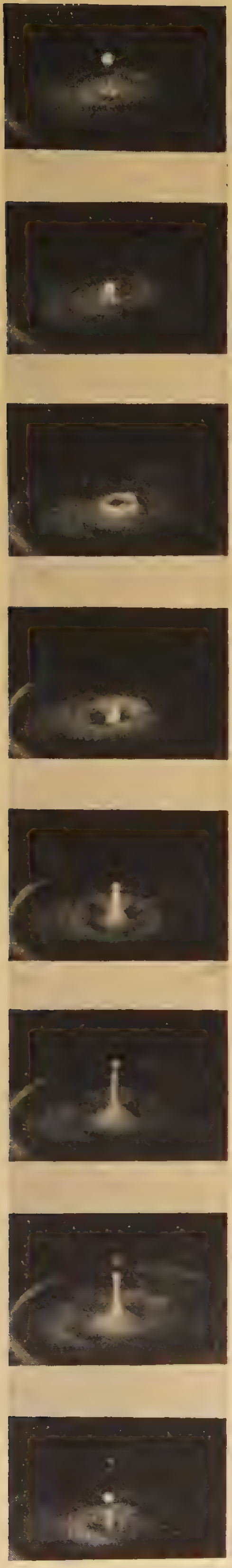


Figure 4

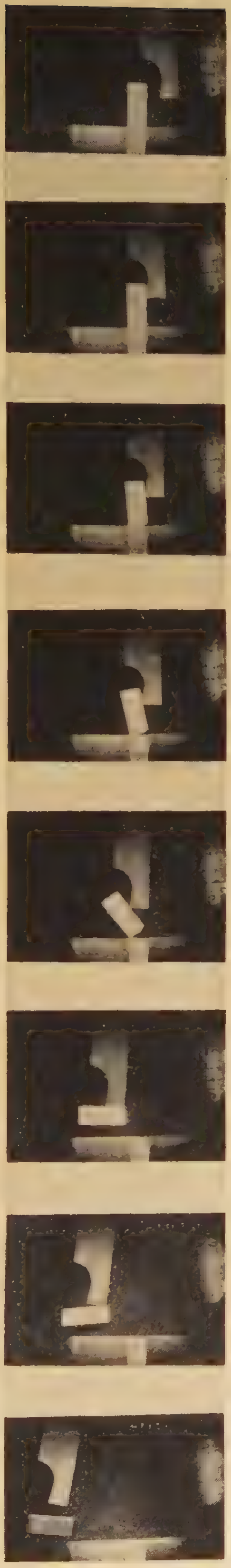


Figure 5

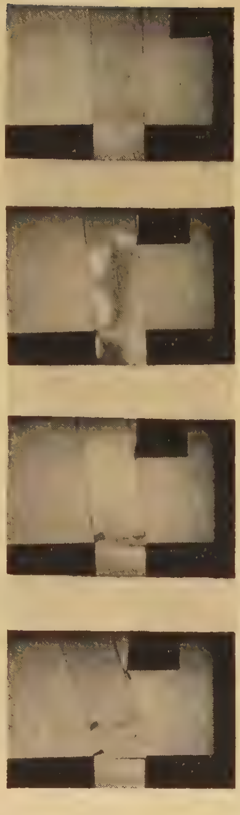


Figure 6

Figure 4. Drop of milk falling into cup of coffee

Figure 5. Breaking of Charpy specimen of hard rubber; note time scale at right

Figure 6. Breaking of impact specimen of glyptol as viewed by polarized light at the time of being struck by the impact hammer; these are said to be the first strain pictures taken with polarized light at high speed

Figure 7. Operation of teletypewriter cam and idler (*A*) and same mechanism (*B*) after redesign; note how much more closely the idler followed the cam after redesign

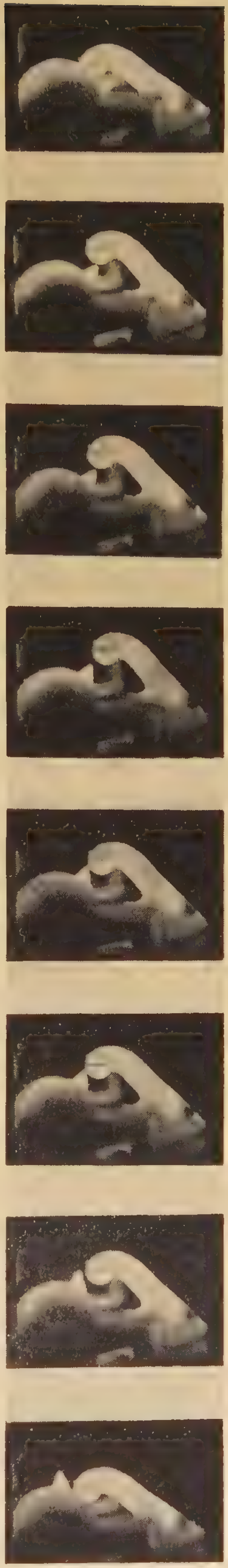


Figure 7*A*

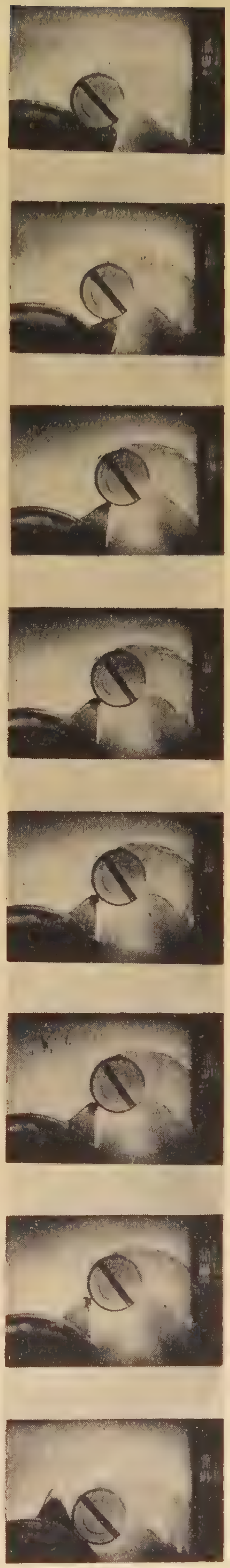


Figure 7*B*

Figures 4 to 7. Enlargements of selected frames from high-speed motion pictures, illustrating versatility of this method of studying high-speed motion

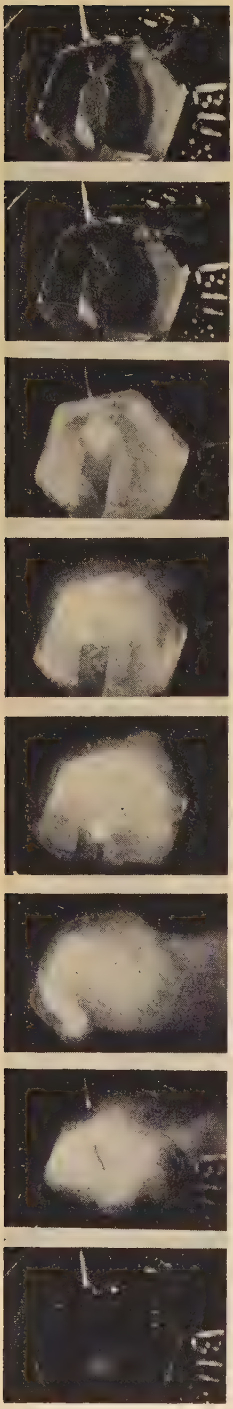


Figure 8. Selected enlarged frames from a high-speed motion picture of the blowing of an ordinary plug fuse

of the ordinary motion-picture camera which uses a mechanical method of bringing the film into position and holding it for sufficient time to permit the proper photographic exposure. This is usually accomplished by means of a rotating shutter, and the film is pulled down a frame at a time by a mechanically operated claw mechanism which engages perforations in the film. Such a camera is severely limited in the number of frames or pictures it may take in a second. The usual limitation is about 80 frames per second, although speeds up to 300 per second are practical. Most of the slow-speed motion studies of athletic events and the like are taken with such a camera. This camera is also useful in taking pictures of mechanical motion of moderate speed.

To obtain a series of pictures of extremely rapid motion would be impossible with such a camera, as the mechanical inertia of the claw mechanism and film would prevent the camera from operating at the requisite high speed with sufficient fidelity of positioning the film uniformly and smoothly behind the lens. Other means of holding an image stationary with respect to the film for sufficient time to permit a photographic exposure must be devised.

A method of doing this, which is employed in the camera developed at the Bell Telephone Laboratories (figures 2 and 3), is illustrated in figure 1. The rays from a point of the object are converged by the lens on the front face of the cube at "*A*"; they are refracted by the glass to the opposite face, pass through it, and form an image on the film at "*a*". When the film has reached a point "*b*", this compensating cube has moved to position "*B*", thus for a brief period the film and the image move at the same speed. The duration of each such exposure is controlled by the speed of rotation of this compensating cube and by the angular height of an aperture in front of each of the four faces of the cube. The cube rotates 1,000 times per second on taking 4,000 pictures per second. The cube is driven by spur gears from a main shaft which is connected directly to a 1/5-horsepower motor. The take-up reel is driven by a separate motor which tends to run faster than the motor driving the sprocket, gear train, and optical compensator, since the latter is more heavily loaded. This causes the film to wind up smoothly. Film passes through the camera at the rate of 70 miles per hour—100 feet in an interval of $1^{1}/_{2}$ seconds—for a taking speed of 4,000 frames per second; 16-millimeter film is used.

These pictures may be analyzed in two different ways. They may be projected or otherwise examined individually or they may be projected as moving pictures at 16 frames per second where the motion may be observed at 1/250 of normal speed. Both of these methods are employed at the Bell Laboratories.

One of the advantages of this method of taking high-speed motion pictures is that subjects may be given studio type illumination in order to bring out the fullest modeling of the subject. The same principles of lighting are used as are employed in any well-equipped studio. The principal difference resides in the intensity of illumination, for using such a high taking speed obviously requires intense lights. Portable light units have been developed which employ tungsten lamps rated, for example, to operate at 70 volts and 750 watts but operated at 120 volts. This raises the temperature of the filament and hence the intensity of the light source. The light intensity varies from 10,000 to 500,000 foot-candles, depending upon the subject, the speed of taking, and the area to be covered. The images of the filaments are projected on the object by using elliptical mirrors behind the lamps. Because of the intense heat, liquid filters are used to absorb this radiation.

A particular field of application for the high-speed motion-picture camera, as already stated, is to study irregular motion that cannot be analyzed by a stroboscope. A further advantage is that the lighting methods that have just been described may be employed, which give better photographic image formation than can be had by a flashing light. It is also possible to work at higher speeds than are practical with a flashing light mechanism because of the difficulty in the latter case of getting sufficiently intense light.

Figures 4 to 8, inclusive, illustrate the usefulness of high-speed motion pictures in studying various types of motion. Illustrative examples of their application to the solution of telephone-apparatus development problems are:

1. Study of mechanism of the teletypewriter (figure 7) which led to redesign of cams and changing the inertia of cam idlers; this was instrumental in reducing impact and noise of operation of the equipment.

2. Study of the vibration of the structure of relays has led to changes in the period of vibration of the component parts and reduction in contact chatter.

3. Study of elastic impact of handset handles has resulted in improved design and material more resistant to service.

4. Study of the motion of the automatic telephone-switching equipment has resulted in design improvements. In fact, all mechanical apparatus that operates at a speed beyond the normal sense of perception is photographed so as to assure that the mechanical parts are operating in the best possible way.

5. High-speed motion pictures have been made of the human vocal cords.

Ceramic Insulating Materials

HANS THURNAUER

A review of the various ceramic materials used as insulation in electric circuits, their composition, methods of manufacture, and characteristics

IN 1898, Professor Reginald Aubrey Fessenden, one of the ablest authorities on the subject of insulation of his time, made the following statement:[1] "I have no hesitation in saying that there are not more than one or two companies in the United States whose insulations are worth more than so much bare cotton cloth after two years' service." The remark referred more especially to the varnishes with which tapes, cloths, and papers were impregnated, but may have been applied to other types of insulation as well. At this time almost any available material which seemed suitable as an insulator was used without much testing or questioning.

Charles P. Steinmetz was among the first to recognize the need for investigating electrical insulating materials, and some of his studies dealt with the dielectric properties of ceramic materials—lava, porcelain, and glass—which were among the first used as electrical insulators. Today the production of technical ceramic products represents a romantic survival of one of the oldest arts developed by the human race. It can be stated, without exaggeration, that our modern electrical system could not be built without the use of ceramic insulation. It is to the credit of the ceramic engineer that an age-old technique has been developed to such perfection that it meets the requirements for modern electrical insulation.

Ceramic materials are used successfully in four general types of electrical applications: low voltage, high voltage, electrical heating, and high frequency. Before discussing the subject further, however, perhaps a definition would be helpful. "Ceramics" is derived from the Greek word, "keramos", meaning potter's earth or clay, a substance found in abundance all over the world. In modern usage, however, it includes all materials that are inorganic and brought to permanent shape and hardness by high temperatures; the heating process results in partial or complete fusion of the constituents and in the formation of compounds not present in the raw materials. This definition comprises a large number of mineral products such as abrasives, cements, enamels, glass, structural clay products, refractories, terra cotta, and white ware.

ELECTRICAL PORCELAIN

Porcelain is, undoubtedly, the best known material among ceramic insulation products. Electrical porcelain is a vitrified mixture of complex silicate compounds bonded together in a glassy matrix. The chief raw materials for porcelain manufacture are of plastic and nonplastic nature: clays, on the one hand; feldspar and flint, on the other.

The plastic constituents, the clays, consist of two kinds: china clay and ball clay. Both of these are hydrous aluminum silicates, resulting from the decomposition of feldspathic rock. Of the two types, china clay is the purer material and burns to a white color. Ball clays have been carried further during the decomposition process and are finer in particle size than china clays; they are mixed with organic matter, such as lignites, which gives them a dark color, but also high plasticity. During the firing process the organic matter is burned out completely and the resultant burned clay is usually of a cream color.

The term "ball clay" is derived from the old English way of mining the material. It was mined in open pits and taken out in the form of balls weighing approximately 33 pounds each. China clay is preferable in body compositions because of its white burning color and its good electrical properties in the fired body. A certain amount of ball clay is necessary, however, to obtain good dry bonding strength and high plasticity, especially for the production of complicated shapes.

It is usual practice to blend clays from various deposits to obtain greater uniformity and to get a combination of properties that cannot be found in one single raw material. The clays are selected for their plasticity, drying shrinkage, dry strength, color, electrical properties, and so forth.

The nonplastic constituents are feldspar and flint. Feldspar is an alkaline aluminum silicate and may be either rich in soda or potash; for porcelain production only the potash variety is used. Feldspar is found in rock formation and mined by quarry operations, then crushed and ground. Since the fusion point of feldspar depends to a large extent upon the fineness of grinding and composition, it is essential that uniformity in particle size and in chemical analysis be maintained, to keep the vitrification range of the porcelain body constant. During the heating process, feldspar fuses and dissolves part of the clay and flint in the body. Flint is ground rock quartz of high purity. It remains inert during firing, but changes its crystalline form. The addition of flint to porcelain bodies reduces firing shrinkage and warpage.

The Chinese, masters in the manufacture of vitrified porcelain, very fittingly compared clay with the flesh, flint with the bones, and feldspar with the blood of the human body.

One of a series of lectures sponsored by the communication group of the AIEE New York Section during the 1939–40 season, and delivered March 18, 1940.

HANS THURNAUER is associated with the American Lava Corporation, Chattanooga, Tenn.

[1] For numbered references see list at end of article.

Properties of Ceramic

	Porcelain		Steatite			
	Wet Process	Dry Process	General Grade	High-Frequency Grade	Low-Expansion Bodies (Cordierite)	Refractory Porcelain
Electrical Properties						
Power factor, per cent, at 1 kilocycle	1	1	0.20	0.06	0.40	
Power factor, per cent, at 1 megacycle	0.7	0.8				
Power factor, per cent, at 10 megacycles			0.18	0.04	0.30	
Dielectric constant	6.5–7.5	6.0–7.5	6.0–6.2	5.8–6.0	5.0	
Dielectric strength, volts per mil	0.2":280		1/4":200	1/4":240	1/4":100	
Capacitance change per deg C			$+1.6\times10^{-4}$	$+1.4\times10^{-4}$		
Volume resistivity, ohm-cm, at room temperature	1×10^{14}	7×10^{12}	1×10^{14}	1×10^{15}	1×10^{13}	1×10^{13}
Te-value†, deg C	300–500	300–500	550	900	650	550
Mechanical Properties						
Specific gravity (bulk)	2.4	2.3	2.5	2.6	2.1	1.9
Water absorption, per cent	Nil	0.5–2	Nil –0.1	Nil –0.1	0.1–1.0	10
Hardness (Mohs scale)	7	7	7.5	7.5	7	7
Tensile strength, lb per sq in. (multiply by 10^3)	6.0	1.0–3.5	7.5	8.0	2.0	0.8–1.0
Compressive strength, lb per sq in. (multiply by 10^3)	55.0	30–40	85	85	50	20–30
Modulus of rupture, lb per sq in. (multiply by 10^3)	11.0	6.0–6.5	18–22	20–24	8–10	3.0–3.5
Resistance to impact, ft-lb Charpy per sq in.	0.9–1.1	0.7–0.9	1.6	1.9	0.7–1.0	0.5–0.7
Modulus of elasticity, lb per sq in. (multiply by 10^6)	7–14	7–12	13–15	13–15	7	
Thermal Properties						
Softening temperature, deg C	1,600	1,600	1,430	1,430	1,400	1,450
Maximum operating temperature, deg C	1,000	1,000	1,000	1,000	1,200	1,200
Linear coefficient of thermal expansion, per deg C (multiply by 10^{-6})	4	3–4	7	7	1.8–2.0	2.5
Thermal conductivity, cgs	0.0025	0.0025	0.006	0.006	0.003	0.002–0.003
Mean specific heat, g-calories per g per deg C	0.2	0.2				0.22

† Temperature in degrees centigrade at which one-centimeter cube has the resistance of one megohm.

In making porcelain bodies, it is essential that an intimate mixture of the ingredients be obtained. This is done by mixing or blunging the finely ground raw materials with water. Where best electrical and mechanical properties are desired, bodies are frequently prepared by pregrinding the nonplastics, flint and feldspar, in pebble mills and adding these wet-ground ingredients to the water-suspended clays in the blunger. The finer structure of the feldspar and flint gives a better mechanical mixture. This makes the materials more active in their properties and effects a better performance of the body throughout the manufacturing process.

After blunging, the body is passed over screens and a powerful electromagnet to remove all traces of free iron which may give faulty spots in the final ware. The body is stored in agitated bins and is ready for filter pressing. The filter presses squeeze out surplus water and produce plastic cakes of uniform moisture content which are ready to go into the pugmill. A pugmill may be described as a screw conveyor which exerts a kneading action to the plastic body and brings particles closer together. Modern pugmills are fitted with vacuum chambers to remove enclosed air.

Electrical porcelain is formed by the three main processes: wet forming, casting, and dry pressing.[2] For wet forming, the plastic material from the pugmill is cut into blanks of desired size and formed either by the hand process, called jiggering, or by machine pressing. The blanks are placed into plaster-of-paris molds. In the jiggering process the mold with the lump of body is set into a revolving head and the ware is formed by a forming tool which is pulled down into the mold on a vertical axis or swung over the arc of a circle.

For high-voltage porcelain, especially suspension insulators, machine pressing is used. In this process, the mold is stationary and the forming tool, traveling on a vertical axis, revolves. After shaping, the molds with the formed insulator parts are put into a release dryer. The plaster-of-paris mold is porous and absorbs moisture from the plastic body. During the drying process, the plastic body shrinks and pieces can be taken from the mold as soon as sufficiently stiff to be handled without distortion. They are then put through a second dryer where they become leather-hard, so that they can be trimmed to accurate dimensions. After trimming, pieces are sent through a final dryer after which they are ready for glazing.

A second method of making wet-process porcelain is to extrude the plastic material into tubes or bars. Either auger machines or hydraulic presses are used for extrusion. The extruded pieces are cut to length and finished after the material is partly or entirely dry. The blanks are turned on a lathe to the desired shape.

Difficult and unsymmetrical shapes can be made by the casting process. The body in cream-like consistency, the so-called "slip", is poured into a plaster-of-paris mold. By the addition of certain deflocculants, like silicate of soda and soda ash, it is possible to produce a fluid material that will pour in a fine stream and contain only a little more water than the plastic material used in wet processing. The plaster-of-paris mold is filled with the casting "slip" and allowed to stand for a certain length of time. The porous plaster absorbs part of the water from the liquid slip and a crust of body forms against the wall of the mold, increasing in thickness the longer the liquid slip remains in the mold. After the deposit has reached the desired thickness, the slip, still liquid in the center, is

Rutile Bodies		Refractory Bodies				Glass				Mycalex	
High Dielectric Constant	Variable Temperature Coefficient of Capacitance	Lava (Radio Grade)	Beryllium Oxide (BeO)	Magnesium Oxide (MgO)	Aluminum Oxide (Al_2O_3)	Flint	Crown	Radio Pyrex	Fused Quartz	General Grade	Radio
0.08	0.06	0.30				0.45	1.0	0.28*	0.03		
						0.40	0.95	0.20	0.02	0.23	0.20
0.06	0.04	0.25									
85	12–85	5.3–5.4				7–9	6–7	4.48	3.7–4.2	8.3	7.5
1/4":200	1/4":200	1/4":100					1/16":400	1/4":350	0.2":340 1/8":200	0.2":340	0.2":360
-6.5×10^{-4}	+1.2 to -6.5×10^{-4}										
1×10^{14}	1×10^{14}	1×10^{12}–10^{14}				1×10^{13}	1×10^{13}	1×10^{14}	5×10^{18}	5×10^{15}	
		700	950–1,100	850–1,050	850–1,050		350	360	721		
3.9	3.6–3.9	2.8	2.0–2.5	2.6–2.8	2.6–2.8	3.7	2.5	2.25	2.2	3.44	2.95
Nil	Nil	1.5	20–50	20–50	20–50	Nil	Nil	Nil	Nil	0.03	0.003
8	7.5–8	6				5	5	5	7	3–4	
6	6	1.8				3–6	2–5		8	5–7	
80	80	20				6–10	10–30	40	20	22–30	
20	20	14								15–20	14–19
1.8	1.8									1.16	
15	15					9.3	9.3	8.86	10.15		
1,500	1,350–1,500	1,500	2,500+	2,500+	2,000+		1,100	600	1,450	450–500	450–500
300	300	1,000	2,000+	2,000+	1,450+			520	1,000	300	300
7–8	6–8	9	7.5	13.4	7.9	7.9	8.9	3.2	0.54	8	
		0.005				0.0020	0.0025	0.0027	0.0036		
					0.18–0.20	0.12	0.16	0.20	0.25	0.2	

* Per cent power factor at 3 kilocycles.

poured out and the cast piece left in the mold until it is sufficiently dry for handling without deformation. After removal from the mold, the method of finishing is similar to that of the wet process.

For dry pressing, the filter cakes are partially dried and disintegrated to a grainy mass. The moist powdered material is put into steel dies and molded under pressure. Porcelain presses may be either hand or power operated. The ware produced by dry pressing is not as dense in structure as that produced by wet process or casting. The dry-pressed porcelain is suitable for only low-voltage applications. It can be worked to good dimensional accuracy, however, especially when made on automatic presses. Special care must be taken with regard to particle size, moisture content, and pressure to insure a uniform product.

As distinguished from the slip method, requiring blunging, filter pressing, and re-mixing, "controlled mixing" has been introduced in several large plants during recent years. This is done by mulling a plastic body having a moisture content of from 9 to 27 per cent. All elements of the mix are proportioned by weight directly into the muller-type mixer, with the proper amount of liquid added, and mulled until complete distribution of raw materials and dispersion of liquids is accomplished. Frequently, chemicals which lower the surface tension of the water and help to speed up penetration of moisture through the clay mixture are added. The amount of liquid, mulling time, and moisture content are positively controlled, resulting in close adherence to required properties of the body, strict uniformity of each batch and high plastic strength. Mulling time varies from 12 to 25 minutes per batch, depending upon raw materials and other factors. The advantages, especially as to speed in operation, over the old method are obvious.

After the ware has been dried, a glaze frequently is applied. A glaze is nothing else but a layer of glass melted to the surface of the body. The glaze on a porcelain body consists essentially of the same raw materials as those used for the body, but in different proportions. The glaze mixture melts to a glass at the temperature at which the insulator is fired. Colored glazes are produced by adding coloring oxides to the glaze mixture. It is essential that a glaze "fit" a body, that is, its thermal expansion and contraction must correspond to those of the underlying body, especially if the piece is used under severe mechanical and thermal conditions. A well-fitting glaze may not have *exactly* the same expansion curve as the body, but can have a slightly lower expansion, thus keeping the underlying body under compression. It has been shown that variations in glaze fit can affect the mechanical strength of porcelain by 200 to 300 per cent.[3]

After glazing, the ware is ready to go into the kiln for firing. The porcelain parts are placed in "saggers" or refractory containers which are stacked on top of each other. These saggers are either put into periodic kilns or on cars to go through continuous tunnel kilns. Firing temperature of electrical porcelain is usually above 1,250 degrees centigrade.

A number of physical and chemical changes occur in the porcelain body during firing. A small amount of mechanically held water is driven out before the temperature reaches the boiling point of water. The next change occurs when the chemically combined water in the clay is driven out. This occurs at about 450 degrees centigrade. With further increase of temperature, the glaze begins to flow and cover the surface of the porcelain. Finally, the softening and fusing of the feldspar grains occur and the liquid spar covers the clay and flint grains. At about the same temperature, the clay particles break up without becoming liquid and change into other crystalline forms of which parts are dissolved in the spar. Even some of the flint is dissolved. These various processes of melting, solution, recrystallization, and crystal changes may be varied with temperature and length of heating, and porcelain with different properties can be produced by merely changing firing rate and temperature.

After firing, the ware must be cooled slowly, to prevent the development of internal strains and cracking. Finally, it is tested, inspected, and ready for shipment, or assembly with metal parts.

Porcelain may be classified, according to its application, into low-voltage and high-voltage porcelain. For low-voltage use it is generally made by the dry-pressing and extrusion processes, whereas high-voltage porcelain is made by the wet and casting processes.

Porcelain for low-voltage use again is graded into four general classes by degree of vitrification:[11]

Class 1 includes parts that have less than 0.25 per cent moisture absorption on whole specimens and less than 0.50 per cent moisture absorption on broken specimens after immersion in boiling water for 30 minutes. Parts for severe atmospheric conditions, such as bases and sockets for outdoor use, fall in this group.

Class 2 permits a moisture absorption between 0.50 and 1 per cent on whole and broken pieces and comprises pieces used under semi-severe service, such as in basements or in protected apparatus installed in outside locations, like tubes and terminal blocks.

Class 3 limits moisture absorption between 1.25 and 2 per cent and applies for porcelain parts, such as screw eyes and protector blocks.

Class 4 includes all porous parts with more than 2 per cent moisture absorption which must have good thermal-shock characteristics, such as resistor cores.

For reduction of moisture absorption, especially in radio receivers, impregnation with organic, moisture-repellant substances, such as ceresin wax, is common practice. The pieces are heated to the melting point of the wax and dipped into the molten wax, preferably under vacuum. Surplus wax is thrown off by centrifuging. Pieces thus impregnated show surprisingly good moisture characteristics. Of course, they cannot be used at temperatures above the melting temperature of the wax without destroying the impregnating film, nor is the dielectric strength of the material improved by such a procedure.

Generally speaking, it may be said that low-voltage porcelain is a desirable insulating material where good mechanical strength, heat resistance, lack of fatigue and cold flow, rigidity, and permanence and, last but not least, low production cost are desirable properties. The disadvantages of porcelain over other types of insulation materials are: low impact strength, limits as to dimensional tolerances, and the necessity of assembling metal parts into finished pieces, rather than molding them permanently into place.

Specifications for high-voltage porcelain are very exacting. It must be vitrified to such a degree that no penetration occurs on a broken surface after immersion in an alcohol-fuchsin dye solution for 15 hours under a pressure of 4,000 pounds per square inch. This high density is of importance for high-voltage work because absorption of moisture, even in traces, results in electrical breakdown under high-voltage conditions.

The three most important properties of high-voltage porcelain are: dielectric strength, mechanical strength, and resistance to sudden temperature changes. All three properties in the very highest degree are not likely to be found in any one body, because they are dependent upon the composition of the body and the various ingredients produce different properties. It has been found that high dielectric strength is characteristic of high feldspar content, high mechanical strength is a function of high quartz content, and high resistance to temperature changes results from high clay content. G. J. Gilchrest and T. A. Klinefelter[4] have drawn a triaxial diagram showing possible porcelain compositions with properties to be expected. Good high-voltage porcelain must have a good working percentage of the three properties, and a good balance is preferable to an optimum in only one direction.

HIGH-FREQUENCY INSULATING MATERIALS

Insulating materials for high-frequency applications require certain properties which are of less importance at low frequencies. As frequencies increase, dielectric losses must be considered.

An insulating material in an electric field consumes part of the electric energy and transforms it into heat. Therefore, "loss" of energy occurs. The loss, N, may be expressed by the following equation:

$$N = E^2 \cdot 2\pi f C \tan\delta$$

where E is the potential, f the frequency, C the capacitance, and $\tan\delta$ the loss factor. The capacitance C can be expressed by two factors—the dielectric constant ϵ and a constant K which depends upon the shape and field position of the insulator. The formula, therefore, may be written:

$$N = (E^2 \cdot 2\pi f K)\epsilon \tan\delta$$

and it can be seen that the dielectric constant ϵ and the power factor $\tan\delta$ are two material constants that are important for the dielectric losses in the insulating material. It further shows that assuming constant loss factor the lost energy increases with increasing frequency f, and the product $\epsilon \tan\delta$ ought to be kept as low as possible, if the insulating material is used merely as a support for a conductor. Where the insulator is used as a dielectric medium in a capacitor ϵ ought to be high, so as to get sufficient capacitance without making the capacitor too bulky or the dielectric too thin. In any case, $\tan\delta$ ought to be low.

Insulating materials for high-frequency use must be rigid and chemically inert. In order to avoid "drift," temperature changes should have no effect upon them. A low coefficient of thermal expansion, therefore, is another requirement for an insulating material used in high-frequency circuits.

In vacuum tubes, insulating materials are required which can easily be degasified and which have low dielectric losses and high insulating resistance at elevated temperatures.

Summarizing, insulating materials with the following properties are required for high-frequency use:

1. Vitrified, mechanically strong materials with low dielectric constant and low power factor for general insulation purposes.
2. Vitrified insulating materials with high dielectric constant and low power factor for capacitors.
3. Insulating materials with low coefficient of thermal expansion for temperature-independent oscillating circuits.
4. Porous or vitrified insulating materials with low dielectric constant and low loss factor for vacuum-tube spacers.

Fused quartz may be regarded as the ideal material for high-frequency purposes because it combines very low dielectric loss with stability and rigidity. Its general application in transmitters or receivers is prohibitive, however, because of high cost of manufacture and because of the limited possibilities of molding this material. Insulators made of quartz glass may be used to some extent in transmitters for ultrashort waves or in precision instruments; they cannot be used where economy of production is a deciding factor.

The manufacture of fused-quartz articles is a highly specialized art. Clear fused quartz is made from high quality clear quartz crystals, or white sand in sufficient state of purity. The raw materials must be acid-treated to remove impurities.

Rods and tubes are generally made in two stages.[5] The crystals are closely packed in graphite crucibles, vacuum applied to the furnace, and the temperature raised to 1,800 degrees centigrade. Enclosed air bubbles rise to the surface of the fused silica. After release of vacuum, pressure is applied by the introduction of nitrogen to reduce the volume of the remaining bubbles to the smallest possible dimensions. The resultant slug is pure and clear. For the forming of small rods and tubes, a slug is heated in a second graphite crucible. A loaded graphite piston is located in the crucible on top of the slug and, as the latter is fused, the molten silica is gradually extruded as a rod or tube through appropriately arranged holes in the descending piston.

Tubes and rods are also made by fusing sand around a central resistor. The core, or resistor, is removed and the silica cylinder withdrawn for drawing into a tube. Other shapes are made according to common glass-manufacturing practice.

Fused silica is an exceptionally good insulator; its mechanical strength is high and its dielectric losses very low. One of the outstanding properties of fused silica is its low coefficient of thermal expansion.

The difficulties of manufacturing quartz glass insulators prohibit their general use, and it is necessary, therefore, to look for other insulating materials with low dielectric losses. Steatite materials combine low dielectric losses with high mechanical and dielectric strength and economy in production.[8]

Steatite is understood to be a group of ceramic materials which contain the hydrous magnesium silicate, talc, as a predominant constituent in the unfired body. Steatite bodies of this definition are fired to vitrification at a temperature of approximately 1,400 degrees centigrade. The final products of thermal decomposition of talc, heated to 1,300 degrees are clinoenstatite and cristobalite; in fired steatite bodies, these crystals can be readily identified.

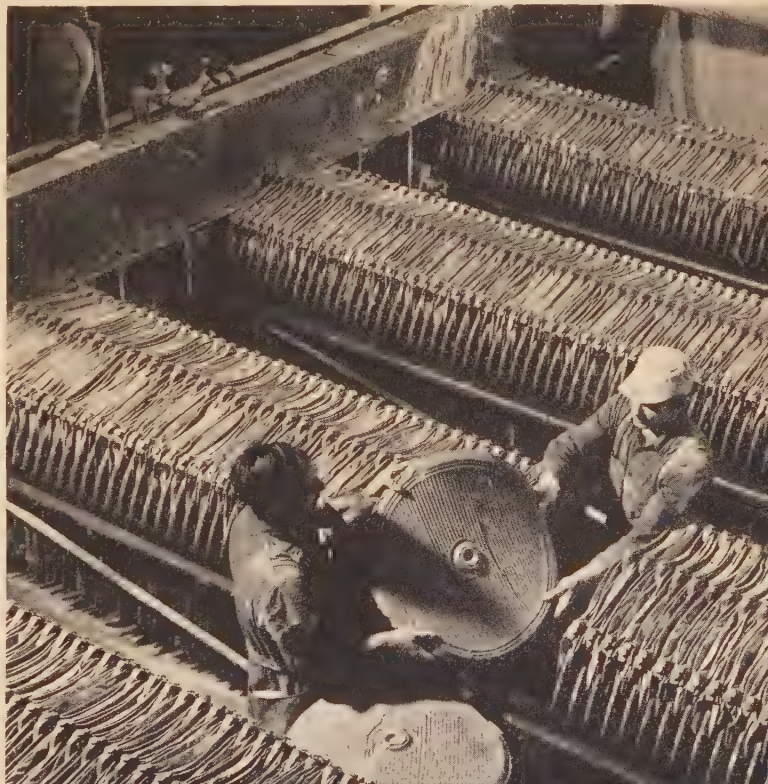
The microstructure of a steatite body is different from that of a porcelain body. Under the microscope, it can be seen that steatite bodies have a very uniform structure, with a predominance of clinoenstatite crystals. Porcelain, however, contains glassy and crystalline matter in about equal portions. This uniformly crystalline microstructure combined with low alkali content is regarded as being responsible for the low dielectric losses of steatite bodies. Reduction of alkalies and further improvements of microstructure resulted in the development of steatite bodies with very low dielectric losses, approaching those of pure quartz.

Steatite insulators are made according to ceramic manufacturing methods described under porcelain, with the exception of the dry-pressing process which is somewhat different from known porcelain practice. Finely powdered talc can be compressed into a compact mass without the addition of moisture. The process, therefore, is truly a dry process. Dry-pressed steatite parts leave the die in a sufficiently hard condition so that they can be handled without danger of distortion and can go directly into the kiln without preliminary drying. They can be manufactured on automatic presses and can be made to great accuracy and density. As examples of dry-pressed steatite parts used in radio receivers may be mentioned trimmer-capacitor bases, socket bases, tube bases, and bushings.

The second group of ceramic materials for high frequency use comprises materials distinguished by a comparatively high dielectric constant and, therefore, suitable for use as dielectrics in capacitors.[14] The manufacture

Removing plastic cakes from filter presses, in porcelain insulator production

Westinghouse



of ceramic bodies with high dielectric constant is one of the latest developments in the ceramic industry. The chief raw material for these materials is titanium dioxide, TiO_2, which has long been known to have a high dielectric constant. The natural mineral, rutile, has a dielectric constant of 183 parallel to its crystal axis and 89 perpendicular to the axis. A crystal mixture has a dielectric constant of 110. By adding fluxes to titanium dioxide, it is possible to produce vitrified ceramic bodies that consist chiefly of a mixture of rutile crystals. The addition of fluxes causes a decrease of dielectric constant to less than 110. The power factor of such bodies at high frequencies is low and within the limits of low-loss ceramic materials. At low frequencies, however, it increases considerably.

Bodies with high dielectric constant of rutile composition are characterized by high negative temperature coefficient of capacitance, which means that the dielectric constant decreases with increasing temperature. This is in contrast with most solid insulating materials which have a positive coefficient. For instance, the dielectric constant of wet-process porcelain changes from 8 at room temperature to 63 at 100 degrees centigrade.

By incorporating, in correct proportions, materials having negative and positive temperature coefficients of capacitance, it is possible to make ceramic bodies that have certain temperature coefficients. Such capacitors are manufactured and served as compensating units in temperature-independent oscillating circuits. They are usually made as thin-walled tubes consisting of the ceramic material with metallic layers fired directly on the outside and inside of the tube. The total unit may be moistureproofed with lacquer, wax, or other organic impregnating compounds or enclosed in a moistureproof ceramic casing. The units are extremely stable and show excellent characteristics under humid conditions.

Thermal expansion coefficients of ceramic materials lie within the range of 1 to 10 times 10^{-6} per degree centigrade. Oxides like those of magnesium (MgO), titanium (TiO_2), and zirconium (ZrO_2), and compounds of these oxides among each other have high coefficients. Steatite bodies have coefficients between 6 and 7 times 10^{-6}; hard porcelain bodies have somewhat lower values—3 to 4.5 times 10^{-6}. Materials of low coefficient of expansion are those which show values below 2 times 10^{-6}. Quartz glass is one of these materials and in this group also belong the so-called "cordierite" bodies which contain a large amount of cordierite crystals ($2MgO \cdot 2Al_2O_3 \cdot 5SiO_2$). Such materials are used to some extent in the construction of temperature-independent oscillating circuits; they are also of importance for parts exposed to sudden temperature changes, such as resistor cores, heating-element supports, and arc chambers.

Refractory ceramic materials of low dielectric losses find various applications as insulators in vacuum tubes. These materials are usually of the porous type. A finely porous material consists of a large number of fine grains or crystals which are connected with each other on only parts of their surfaces. The voids between the grains are open and, during evacuation, it is possible to remove all traces of gases throughout the porous material. Another advantage of porous materials as insulators in vacuum tubes is that no coherent metal layers can deposit over the surface of the insulator, in case metal vapors are given off in the tubes.

The material most widely used for vacuum tube spacers is "lava," or burned soapstone. The raw material is the well-known hydrous magnesium silicate mineral talc which is machined in its natural condition and then burned to hardness under certain conditions of time and temperature (1,800 degrees Fahrenheit or approximately 1,000 degrees centigrade). For spacers in vacuum tubes, only selected materials are suitable, which must be as free from iron oxide as possible. For better evacuation, pieces are fired in a hydrogen atmosphere before use. These spacers made from natural stone have been replaced, to some extent, by materials made from powdered raw materials and dry-pressed under high pressure. Such spacers are usually made either from a material having powdered talc or alumina as the chief ingredient.

Vacuum-tube cathode insulators are made of refractory oxides of high purity.[17] These insulators get white hot during use and only the most refractory materials—such as beryllium oxide, magnesium oxide, aluminum oxide, or thorium oxide—are suitable for this purpose. The art of making these insulators has been perfected by only a few companies which make very small tubes, rods, and other shapes from these oxides. These insulators probably represent the smallest ceramic articles on the market.

GLASS

Glass is one of the oldest materials manufactured by man. It has been described as an undercooled liquid "whose rigidity is great enough to enable it to be put to certain useful purposes" (Morey).[10] Its chemical composition varies widely, but in general it can be said that silica (SiO_2) is the foundation of all commercial glasses, fused with such basic metallic oxides as soda and potash and with other oxides such as those of calcium, lead, barium, magnesium, and boron. The properties of glasses are primarily determined by their compositions.

Silica is ordinarily introduced into the glass batch as flint, sand in finely powdered form. For the manufacture of clear glass, it must be as free from iron oxide as possible. Alkalies are introduced in the form of soda ash (Na_2CO_3) and potash (K_2CO_3); lime is added as limestone ($CaCO_3$); barium, as witherite ($BaCO_3$); and lead, as red lead (Pb_3O_4). Furthermore, cullet or broken glass is added to utilize waste and to assist in initial fusion.

The finely divided raw materials are weighed, mixed, and melted in pot or tank furnaces, depending upon the amount of charge or grade of glass. After melting, forming is done either by hand or automatic blowing, casting, rolling, or molding. These various processes take advantage of the characteristic of glass that it has no definite melting point, but changes its viscosity gradually when going from the liquid to the solid state.

A final, but very important, step in the manufacture of glass is annealing. The process consists of very gradually cooling the heated articles, usually done by carrying the ware on a conveyor through a heated oven, the so-called "lehr." This slow cooling process is carried out to regulate internal strains which may cause cracking of the piece during use.

The first requisite in a commercial glass is that it not be subject to devitrification; fortunately, glasses that meet this requirement show a large variation in composition. Most commercial glasses contain silica as the chief constituent, and silica or flint glasses possess the important quality of superior resistance to weathering. Silica, incidentally, is the most common and cheapest of the glass-forming materials. Silica itself possesses, in the highest degree, the desirable quality of resistance against weathering and freedom from devitrification, and, if it were not so difficult to melt, it would be the most suitable material for the various uses to which glass is put.

The most widely used glasses are of the soda-lime type, consisting chiefly of lime (CaO), soda (Na_2O), and silica (SiO_2) in the proportions determined primarily by the low ternary eutectic of the system. Soda glass, or "crown glass", of the eutectic composition, however, is too susceptible to weathering and atmospheric conditions, and most soda glasses contain an excess of lime over the eutectic mixture and also additional small amounts of the oxides of magnesium (MgO), aluminum (Al_2O_3), and boron (B_2O_3) to increase chemical stability and to obtain other desirable properties. The so-called "resistance glasses" are modifications of the ordinary crown type but contain more aluminum, boric, or zinc oxides than is usually used in ordinary crown glass.

Another important group of glasses comprises the lead glasses, characterized by the presence of lead oxide, ranging from 20 to 80 per cent. This series of glasses is of great importance in lens design. Lead glasses with very high lead content are used for protective shields against X rays.

Pyrex glass differs from all other types in not being derived in any way from an alkaline heavy oxide, eutectic, but rather from silica glass by the addition of boric and aluminum oxides, with a minimum quantity of alkaline oxide. It is a borosilicate glass and its main characteristics are good mechanical strength, low coefficient of thermal expansion, chemical stability, and good dielectric properties. Pyrex is not the name of one material, as is frequently assumed, but is a trade mark of the Corning Glass Works covering various thermally, electrically, or chemically resistant glasses of different compositions.

Glass insulators are used extensively as pin-mounted line insulators for open-wire lines, and Pyrex glass is especially suitable for such purposes because of its good weathering qualities and resistance against thermal shock. During recent years, glass line insulators have been improved considerably, and the inroads they are making to replace porcelain are noticeable. One advantage of glass, compared with porcelain, is its ability to transmit light. It has been found that an opaque insulator, like porcelain, encourages insects to build nests between pin and insulator, thus providing a current leakage path. For the same reason glass insulators do not heat as much under the light rays of the sun as do porcelain insulators.

Glass, as an electrical insulator, may be found in insulating supports, radio-antenna insulators, radio power-tube bases, capacitor insulation, and line insulators.

For the manufacture of bulbs for incandescent lamps and for electronic tubes, glass must be uniform as to softening temperature and ease of working. The coefficient of expansion must be considered wherever a glass-to-metal seal is applied. Today it is possible to obtain glasses with definite temperature coefficients of expansion within the possible range of glasses, meaning approximately from 2.0 to 10×10^{-6}. This is important for the manufacture of mercury switches, vacuum tubes, and other devices.

One of the most recent technical developments and achievements of the glass industry is the commercial manufacture of *fiber glass*,[16] thus introducing a new insulating material for electrical apparatus. The idea of stretching glass into fibers goes back to antiquity, but only recently has the idea been converted into commercial use. Venetian glass blowers made use of glass fibers for intricate designs on glass ware. The glass blower heated a lump of glass until it became plastic, and his apprentice seized one corner with a pair of tongs and raced away as fast as he could run. Depending upon the speed of the apprentice, a more or less fine fiber was produced. It did not take very long for the apprentice to be replaced by a rotating wheel on which the glass fiber was continuously wound, and our museums contain dresses and other garments made of spun glass during the 17th and 18th centuries.

During the last few years glass companies have undertaken the commercial production of glass fibers and now produce threads with a diameter of 0.0002 inch or about 1/15 the size of the average human hair. They can be spun into thread and woven into cloth. Coarser fibers are used for thermal insulation.

The textile glass fibers are made by two distinct types of manufacture and can be divided into two classes. In each type, glass marbles are fed into small electrically heated furnaces. The molten glass flows by gravity through a row of fine holes in a precious metal die or bushing and comes out as fibers. In order to make these fibers fine, they are either stretched while hot by being wound upon a rapidly rotating drum or they are pulled out into a rapidly descending column of steam which breaks up the fiber into 4- to 8-inch lengths (called staple fiber) and deposits them on a continuously moving belt as a narrow felt or sliver.

The continuous-filament glass produced by the first method may be spun directly into a thread, whereas the sliver of the second method may be reduced in size before spinning; it makes a rougher finish than the continuous thread.

Glass threads may be woven into cloths by using ordinary cotton machinery with slight modifications. Glass textiles look very much like textiles made of rayon or silk. For most electrical uses, the important requisites are good mechanical strength and electrical properties as well as resistance to deterioration from high temperatures and from the action of chemicals, moisture, and dirt. To meet these requirements, special glasses free from alkalies had to be developed. Alkali-free fiber glass is practically unaffected by moisture or mild alkalies and acids, with the exception of hydrofluoric acid. It is flexible and extremely strong. However, if the fibers are allowed to rub and abrade, they nick and break. This action may be prevented by proper varnish or compound treatment. By coating the fiber with a small amount of oil, fibers can be spun satisfactorily and the resulting fabric does not need any further treatment except for wire insulation which must withstand the severe abrasion often encountered in winding operations.

Fiber-glass structure is porous and can be considered only as a physical spacer unless filled with an organic insulating compound. Treated fiber glass has the desirable characteristic of good dielectric strength and low dielectric constant, but does not possess the voltage breakdown strength of mica tape, particularly after aging at high temperatures. Treated fiber glass is, therefore, vitally dependent on the impregnating compound for dielectric strength and limited in temperature endurance to a range between 125 and 175 degrees centigrade. Treated fiber glass, therefore, should not be exposed to temperatures above the working temperature of its impregnating compound.

MYCALEX

Mica is the most important of mineral insulating materials, but, since the material is used in the natural state without subsequent heating, it cannot be considered as a ceramic material and its description at this place is out of order. Many forms of micas are known to the mineralogists for electrical use; however, only muscovite and phlogopite are of interest. Micas are complex compounds of silica and may be regarded as orthosilicates of aluminum with alkaline metals (potassium, sodium, lithium, and also magnesium, iron, and fluorine). Muscovite is potassium mica; phlogopite is magnesium mica.

Since mica can be obtained only in limited sizes and thicknesses, attempts were made to bond mica flakes with moldable compounds, either of organic or inorganic nature, and compress the mixture, preferably under heat, into a compact mass to desired size and shape.

The best known among mica-compound insulating materials is Mycalex,[15] which is the invention of P. B. Crossley of England and is manufactured in the United States by the General Electric Company. One of the original objects of the invention was to utilize waste mica scraps and dust, and the result was a product having electrical characteristics approaching those of mica and mechanical properties approaching those of metal.

Mycalex is composed of ground mica and lead borate glass. Both these ingredients have high dielectric strength. The materials are prepared in a fine state of division and intimately mixed. For preforming blanks, the material is pressed cold similar to dry-pressing other ceramic materials. The pressed blanks are dried, heated to approximately 700 degrees centigrade in an electric furnace, and finally pressed in an electrically heated mold.

Metal inserts can be molded into Mycalex pieces, which adds greatly to convenience of design and economy in assembly. This is in contrast with the manufacturing procedure for other ceramic products where firing shrinkage and high firing temperatures make it impossible to mold metal inserts directly into insulators. Since Mycalex is never really plastic during forming, only relatively simple designs and metal inserts can be manufactured without unduly increasing the cost.

Another unique feature of Mycalex as a ceramic product is that it can be subjected to all the usual machining operations, such as drilling, filing, sawing, polishing, and punching. Stone-like ceramic materials, such as steatite and porcelain, are too hard to be machined by a metal tool and can only be lapped and ground with the hardest abrasives, like silicon carbide, alundum, or diamond dust. The wear on tools is greater than in ordinary metal-machining processes, and, in some instances, special tools may be required.

Aluminum alloys can be cast around the material without affecting its structure. By this method, fittings can be cast over the ends of rods to form strain insulators, thus eliminating the necessity of machining and fastening the fixture to the insulator.

Two grades of Mycalex are available: a general purpose grade, and a radio grade with low and uniform power-factor characteristics. This latter grade is smoother and less porous. It is the preferred grade where changing atmospheric conditions may adversely affect the electrical insulating properties of other grades of Mycalex.

Mycalex is used in radio apparatus, particularly in radio transmitters, because of its good insulating properties at high frequencies. Specific applications are in high-frequency switches, coil supports, control shafts, and radio antenna insulators.

VITREOUS ENAMELS

Vitreous enamels may be defined as easily fusible silicate substances, consisting of a colorless glass rendered opaque by the addition of metallic oxides and frequently colored by the addition of coloring metal oxides, commonly used in glass manufacture. Vitreous enameled products are used extensively for decorative, protective, and insulating purposes. Their description here is limited, however, to their application as electrical insulators.

Raw materials used in the preparation of enamels are numerous; among the more important ones are: flint, feldspar, borax, cryolite, fluorspar, sodium nitrate, antimony compounds; the oxides of lead, zinc, tin, magnesium, and zirconium; and coloring oxides like those of cobalt, iron, manganese, chromium, nickel, and uranium. The selection of raw materials and their proportions depends on the material to be enameled and the fusion temperature desired. The raw materials are finely ground, mixed together, and melted in a furnace. The liquid melt is poured into water where it freezes to a glass and at the same time breaks up into small shattered glass particles. These glass particles, the so-called "frit" which is not soluble in water, are ground to fine powder and mixed with water and either clay or organic suspension agents to help keep it suspended in water.

Metal parts to be enameled must be free from surface impurities and are thoroughly washed and treated with acids to remove oxide coatings. Otherwise, good adherence to the surface cannot be assured. On metal parts usually a ground coat is applied first, either by dipping, spraying, or dusting on the dry pulverized enamel composition. After applying the ground coat, the pieces are fired in a furnace at a temperature of approximately 850 degrees centigrade. The ground coat merely provides a suitable layer, the coefficient of expansion of which is between that of the metal part and the top enamel coat. The final enamel coat on top of the ground coat is fired at a somewhat lower temperature than the ground coat.

The enamels are extensively used to cover resistors of the wire-wound core type. For this application, enamels with several properties unusual for most enamels are required. It is important that the thermal coefficient of expansion between ceramic tube, wire, and enamel are close together to minimize crazing of the enamel coating. Furthermore, the enamel must be melted on at a temperature as low as possible to prevent oxidation of the wire and subsequent change of resistance values. Such enamels are usually melted on at a temperature of about 650 degrees centigrade and have a high lead and boron content. The underlying ceramic core may be either vitrified or porous, but must be of such composition that it withstands the rapid temperature changes during enameling and during the use of the resistor.

Another interesting application of enamels is as an insulating coating for the screens in television camera tubes. The insulating material for this purpose should have the following qualifications: It must be inert to the chemical action of the activating agent and have low vapor pressure; it must withstand the temperature encountered in the baking required for outgassing of the tube during exhaust and adhere firmly to the screen without cracking or flaking off during the heating; and, finally, it must have high specific resistance. Special enamels having these properties have been developed for this application.

Competition between ceramic and plastic materials is growing stronger daily, and there is no doubt that certain products made of ceramic materials today will be made of one of the organic plastic materials tomorrow. The art of making organic plastics has advanced during recent years to a greater extent than that of making any other type of insulation. New materials have been brought on the market which are both beautiful and can be molded into most intricate shapes as well as having excellent dielectric properties. This, however, is not discouraging to the ceramic industry and has rather stimulated developments in the inorganic field. Ceramic development and improvements are going on, although not at quite as rapid a pace as in the plastics field.

Two outstanding inventions may be mentioned here which have had rather wide publicity, but are not ready to go into production. The first of these is glass having an extremely low coefficient of expansion and excellent heat resistance. This is a development of the Corning Glass Works and has been discovered during investigation on Pyrex glass. This new glass consists of practically pure silica and has the properties of this material. A glass of Pyrex composition is molded into the desired shape by the well-known methods of forming glass. It is then subjected first to a heat treatment and then to an acid treatment that dissolves all oxides with the exception of silica and leaves silica as a porous skeleton. By a second heating process the porous article is vitrified. The vitrification causes a volume shrinkage of approximately one-fifth of the original size. Bowls made from this new material do not crack when filled with molten lead while resting on a block of ice. The advantages of a material of this type for the electrical industry are obvious. No doubt it will be a valuable addition as a high-frequency insulator.

The second invention is so-called "Alsifilm". This invention originated at the Massachusetts Institute of Technology and consists of the production of a very thin film of ceramic material that can be used in place of mica. Mica is on the list of necessary war materials which must be imported, and a substitute that can be manufactured in the United States would be a very desirable product. Alsifilm is produced by depositing powdered bentonite, a hydrous aluminum silicate, in a very fine state of division on the walls of a centrifuge. The material can be made into sheets of about 0.002 to 0.003 inch thickness, and these sheets are flexible enough so that they can be used in the same manner as natural mica.

REFERENCES

1. Discussion on Insulation and Conduction, **Reginald A. Fessenden.** AIEE Transactions, volume 15, 1898, page 156.

2. Manufacture of Electrical Porcelain, **R. L. Whitney.** Electrical Engineering, volume 58, January 1939, pages 7–11.

3. How Surface Characteristics Effect Strength of Ceramic Materials, **D. H. Rowland.** *Ceramic Industry*, volume 28, 1937, pages 212 and 217–18.

4. Electrical Porcelain, **G. J. Gilchrest** and **T. A. Klinefelter.** *Electric Journal*, volume 15, February 1918, pages 36–39.

5. Electrical Insulating Materials (book), **H. Warren.** Ernest Benn Ltd., London, Eng., 1931.

6. Electrical Engineers' Handbook—V, Electric Communication and Electronics, **H. Pender** and **K. McIlwain,** John Wiley and Sons, Inc., 1936.

7. The Insulation of Electrical Machines (book), **Turner** and **Hobart.** Whittaker and Company, 1905.

8. Hochfrequenz Keramik (book), **Ernst Albers-Schönberg.** Th. Steinkopff, Dresden and Leipzig, Germany, 1939.

9. High-Voltage Porcelain Insulators, Their Design and Manufacture. Special Publication 1690, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

10. The Electrical Properties of Glass (book), **J. T. Littleton** and **G. W. Morey.** John Wiley and Sons, Inc., New York, 1933.

11. Ceramics in the Telephone, **A. G. Johnson** and **L. I. Shaw.** *Industrial and Engineering Chemistry*, volume 27, November 1935, pages 1326–32.

12. Some Ceramic Manufacturing Developments of the Western Electric Company, **A. G. Johnson** and **L. I. Shaw.** *Bell System Technical Journal*, volume 18, April 1939, pages 255–79.

13. Properties and Preparation of Ceramic Insulators for Spark Plugs. National Advisory Committee for Aeronautics, Report No. 53, Government Printing Office, Washington, D. C., 1920.

14. Review of Ceramic Materials for High Frequency Insulation, **Hans Thurnauer.** *Journal* American Ceramic Society, volume 20, November 1937, pages 368–72.

15. G. E. Mycalex, an Inorganic Material of the Ceramic Type. General Electric Company Publication GET-903, Filing No. 6900.

16. Fiber Glass, A New Insulation for Electric Apparatus, **K. N. Mathes.** *General Electric Review*, May 1938, page 218.

17. Extrusion of Refractory Oxide Insulators for Vacuum Tubes, **Louis Navias.** *Journal* American Ceramic Society, volume 15, 1932, pages 234–51.

18. Beryllium Oxide, **H. E. White** and **R. M. Stremp.** *Journal* American Ceramic Society, volume 22, June 1939, pages 185–9.

19. Asbestos and Glass Fiber Magnet-Wire Insulation, **K. N. Mathes** and **H. J. Stewart.** AIEE Transactions, volume 58, 1939, page 290.

20. Glass as an Electrical Insulator, **C. J. Phillips.** *Journal of Applied Physics*, volume 11, 1940, pages 173–81.

Frequency-Selective Feedback for Audio Systems

W. N. BROWN, JR.
ENROLLED STUDENT AIEE

E. W. SHERIDAN
ENROLLED STUDENT AIEE

THE performance of the majority of sound systems is limited by the frequency response of the loud-speaker. The frequency distortion inherent in all but the most expensive loud-speaker equipment can be compensated by modifying the gain frequency characteristics of the associated amplifiers by the use of feedback. Not only can the relatively poor frequency response of the average loud-speaker be compensated, but it is possible also to modify the response of a system by this method so that the sound can be reproduced naturally at higher or lower intensity levels.

As a loud-speaker has an irregular frequency response curve, it is practicable to compensate only for general trends in the feedback network, particularly since the humidity and temperature changes often cause the frequency at which a sharp speaker resonance occurs to deviate from its normal value by as much as 20 per cent. The most objectionable resonances cause a decrease in load on the amplifier and a corresponding increase in the voice-coil terminal voltage. At frequencies where these resonances occur, voltage is fed back degeneratively from the voice-coil terminals in order to reduce the effect of the resonances.

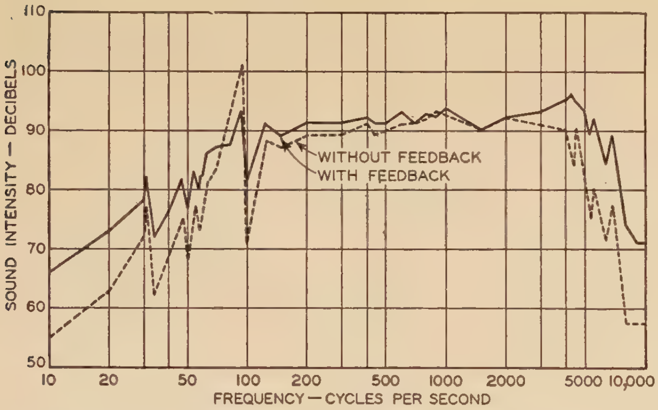


Figure 1. Acoustical response of a typical audio-frequency system with and without frequency-selective feedback; signal input was ten decibels greater when feedback was used

The method, then, consists essentially of using feedback to alter the character of the signal in the electric circuit of the amplifier in such a way as to counteract the undesirable alteration that takes place in the speaker. This is effected, first, by introducing correction in the feedback network for general speaker trends, and, second, by obtaining degenerative feedback voltage from the voice-coil terminals to counteract sharp resonances and wave-form distortion.

Practically, the important factor limiting the compensation is the maximum decrease in the system's useful power output that can be tolerated. In general, if the amplifier itself has a reasonably flat frequency response, the reduction in speaker power output will be about equal to the maximum range of compensation obtained from the feedback. However, this statement applies only to a signal whose power is evenly distributed over the frequency spectrum. Since this condition does not ordinarily obtain in practical applications, the actual reduction in useful power output may be much less than the range of compensation, and for some types of program may be negligible. The reduction of useful power output arises from the fact that the acoustic response of the system can only be flattened electrically by reducing the speaker input at the frequencies where it is most efficient, in order to bring the acoustic output at these frequencies down to what it is at the frequencies where the speaker is less efficient. In other words, the electrical compensation is obtained by reducing power, not by increasing it.

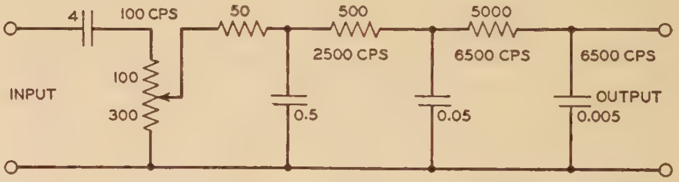


Figure 2. Feed-back network used to achieve the results indicated in figure 1

The network is fed from the voice-coil terminals of the loud-speaker; the output preferably feeds into the grid circuit of the second stage of the amplifier in order to make the amount of feedback independent of the internal impedance of the signal source. All resistance values shown are in ohms and capacitance values in microfarads; cut-off frequencies of the various network sections are indicated in cycles per second (CPS)

Some of the important advantages of this method are:

1. The frequency response of a given system is greatly extended.
2. The variation with intensity level of the frequency response of the human ear can be compensated.
3. A reduction in distortion of wave form by the amplifier or by the speaker takes place at the frequencies where the feedback is degenerative.

Abstracted from a paper "Frequency-Selective Feedback for Improvement of Acoustical Response of an Audio-Frequency Sound System," presented at a student session of the AIEE North Eastern District meeting, Springfield, Mass., May 5, 1939; subsequently awarded, jointly with another paper, the AIEE national prize for Branch paper for the academic year ending June 30, 1939, which award was presented at the Institute's recent 1940 summer convention.

W. N. BROWN, JR., was a student at Massachusetts Institute of Technology, Cambridge, when this paper was prepared; he is now research assistant in the electrical-engineering department of that institution. E. W. SHERIDAN also was a student at MIT when the paper was prepared; he is now connected with RCA Manufacturing Company, Camden, N. J.

4. The mechanical resonances of the speaker are reduced at the frequencies where the feedback is degenerative.

5. The effect of hum and noises not present in the input signal is reduced when they occur at frequencies where the feedback is degenerative.

However, the system has the disadvantage that the ratio of output power to input voltage is less with feedback than without feedback; furthermore, the maximum useful output power is less with feedback than without feedback. Moreover, distortion of wave form is accentuated at frequencies where feedback is positive. These disadvantages are not of very great importance in most practical cases.

An Electronic Relay for Initiating Vapor Discharges

EDWARD C. DENCH
ENROLLED STUDENT AIEE

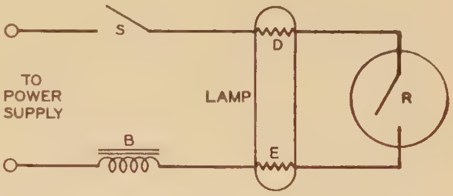
THE recent introduction of low-voltage fluorescent lamps has created a need for automatic control auxiliaries. Several methods have been devised for the automatic starting and operation of these lamps, the most recent being a device known as the "glow relay".* Earlier methods had certain disadvantages as to cost, effect on the lamps, circuit efficiency, dependability, and ease of wiring. The invention of the glow relay resulted from attempts to overcome these undesirable features.

The relay is essentially a small glow-discharge lamp, comprised of two electrodes in a glass envelope containing neon. The container is about the size of an automobile headlight lamp. One of the electrodes is constructed of a heat-sensitive bimetallic strip with a contact member at its extremity. The other electrode is a projecting wire placed so that it will touch the contact member when the bimetallic strip flexes due to heating.

When a gaseous glow discharge takes place in this device, the bimetallic strip is heated by positive-ion bombardment and flexes so that the contacts are closed. When the contacts make an electrical connection, the glow discharge is short-circuited. The device is designed to have a breakdown voltage of about 90 to 100 volts. This relay, labeled *R*, is connected in the fluorescent lamp circuit as shown in figure 1.

When the control switch *S* is closed, line voltage of say 110 volts is applied to the relay through the lamp electrodes *D* and *E* and the current-limiting reactor *B*. The line voltage causes breakdown of the neon in the relay, and a glow-discharge ensues. The bimetallic strip then becomes heated; it flexes and causes the contacts to engage, short-circuiting the glow, and permitting electrode-heating current to flow in the lamp. After the glow-discharge is short-circuited, the bimetallic strip cools and the contacts subsequently open, breaking the circuit and causing a high voltage to be induced in the series inductance. This high voltage is of sufficient magnitude to insure definite initiation of the mercury-vapor discharge of the lamp.

Figure 1. Schematic diagram showing how relay is connected to low-voltage fluorescent lamp



After initiation of the discharge, the lamp begins to operate and its terminal voltage drops to about 60 volts. This voltage also is applied to the relay, but is insufficient for the formation of another glow-discharge in the relay, thus preventing further operation of the relay while the lamp is operating.

The glow relay has many advantages over previous fluorescent-lamp automatic-starting devices. In breaking the electrode heating current it causes voltages to be induced in the reactor which insure positive breakdown of the lamp. The device does not operate and consume power once it has started the fluorescent lamp; consequently the circuit efficiency is not affected by its presence. It has but two electrical connections, thus permitting a simplicity of wiring. The relay has exceedingly long life. In an actual test, one relay has started fluorescent lamps over 1,000,000 times. The relay is not sensitive to changes in room temperature; it does not hum; it is inexpensive and compact. In starting and restarting a lamp after a power interruption, it acts quickly and effectively. In addition, it may be stated that the relay, although first developed for use with fluorescent lamps, is not limited to use with these particular lamps. It may find application in the automatic control of other discharge devices of the same nature which exhibit the same phenomena.

Abstracted from a paper "The 'Glo-Relay', A New Method of Initiating Vapor Discharges," presented at a student session of the AIEE North Eastern District meeting, Springfield, Mass., May 5, 1939; subsequently awarded, jointly with another paper, the AIEE national prize for Branch paper for the academic year ending June 30, 1939, which award was presented at the Institute's recent 1940 summer convention.

EDWARD C. DENCH was a student at Worcester Polytechnic Institute, Worcester, Mass., at the time this paper was prepared; he is now affiliated with Interchemical Corporation Research Laboratories, New York, N. Y.

* The Westinghouse "glow relay" was invented by the author during summer-vacation work for the engineering laboratories, lamp division, Westinghouse Electric and Manufacturing Company, Bloomfield, N. J. Further development work, bringing the relay to its present form, is credited to the members of the vapor lamp development department of that company under the direction of D. S. Gustin.

A Graphical Solution of Transient Stability

H. H. SKILLING
MEMBER AIEE

M. H. YAMAKAWA
ASSOCIATE AIEE

An extension of the equal-area method of determining transient stability limits, applicable to power systems that can be reduced to two equivalent machines

THE equal-area method gives a simple criterion for the determination of transient stability of a power system in which the synchronous machinery can be reduced to two equivalent machines, but it alone is not adequate when switching or other secondary disturbances of the system follow the initial disturbance. The method here proposed is an extension of the equal-area method. Its advantage lies in the fact that it gives angular position of the synchronous machine as a function of time; it gives, in other words, a swing curve. It thereby permits the general method of the equal-area solution to be applied to system disturbances in which time is a factor. It can be used, for example, to study switching operations following a fault.

The proposed method is essentially one of graphical integration, based upon the power-angle curve of the system. It is considerably less laborious than a step-by-step solution of comparable accuracy. It is restricted, as is the equal-area method, to systems to which power-angle curves can be applied, but unlike the latter it will readily include the effect of damping (either positive- or negative-sequence damping), governor action, and other effects that are functions of time or velocity. Change of flux linkages within the synchronous machines can be introduced into the solution with a fair degree of approximation if desired. Accuracy of computation by this method has been checked experimentally, and also by comparison with other methods.

THEORY

The power input to a synchronous machine is consumed in three ways: power output, power consumed in damper windings and other losses, and power used in accelerating the rotating part of the machine (this may be either positive or negative) thereby altering its kinetic energy.[1] Denoting the difference between power input and output by ΔP:

$$P_i - P_o = \Delta P = P_d + P_a \tag{1}$$

(All notation is tabulated at the end of the article.) Neglecting damping, for simplicity in this introductory discussion:

$$\Delta P = P_a \tag{2}$$

The power that produces acceleration of the rotating machine is equal to the product of the torque that produces acceleration and the angular velocity of the machine:

$$P_a = \omega T_a \tag{3}$$

During any transient disturbance from which recovery of synchronism of the system is to be expected, ω does not vary more than a few per cent from synchronous angular velocity. It is therefore approximately correct to write:

$$P_a = \omega_s T_a \tag{4}$$

In these equations, T_a is the product of the angular acceleration of the machine and its moment of inertia:

$$T_a = \alpha I = \frac{d\omega}{dt} I \tag{5}$$

The angular velocity at any instant may be considered to have two components, one the normal synchronous velocity, and the other the velocity due to the transient disturbance:

$$\omega = \omega_s + \Delta\omega \tag{6}$$

from which it follows that:

$$\alpha = \frac{d\omega}{dt} = \frac{d(\omega_s + \Delta\omega)}{dt} = \frac{d(\Delta\omega)}{dt} \tag{7}$$

The angular position of the rotor of the machine, θ, changes because of both the synchronous component of velocity and the incremental velocity produced by the transient disturbance:

$$\theta = \theta_s + \Delta\theta \tag{8}$$

and since

$$\omega = \frac{d\theta}{dt} \tag{9}$$

it follows that

$$d(\Delta\theta) = (\Delta\omega)dt \tag{10}$$

The angle δ is the power angle of the machine (this is common usage). It differs from the angle $\Delta\theta$ in the foregoing discussion by a constant angle: When the machine is in its steady running position, before a transient disturbance occurs, $\Delta\theta = 0$, while $\delta = \delta_o$. Therefore

$$\Delta\theta = \delta - \delta_o \tag{11}$$

Now consider the integral

$$\int_{\delta_o}^{\delta} P_a d\delta = \int_{o}^{\Delta\theta} P_a d(\Delta\theta) \tag{12}$$

Substituting into this equations 4, 5, 7, and 10:

$$\int_{\delta_o}^{\delta} P_a d\delta = \omega_s I \int_{o}^{\Delta\omega} (\Delta\omega) d(\Delta\omega) = \omega_s I \frac{(\Delta\omega)^2}{2} \tag{13}$$

H. H. SKILLING is associate professor of electrical engineering, Stanford University, Calif. M. H. YAMAKAWA, recently a graduate student in the department of electrical engineering, Stanford University, is at the Imperial University of Tokyo, Tokyo, Japan.

[1] For numbered references see list at end of article.

The product $\omega_s I$, an inertia constant of the machine, hereinafter is designated by G; that is, $G=\omega_s I$ (further discussion of this quantity is given in the discussion of "Units"). Introducing this symbol, equation 13 gives:

$$\Delta\omega=\sqrt{\frac{2}{G}\int_{\delta_0}^{\delta}P_a d\delta} \qquad (14)$$

From equation 10:

$$dt=\frac{d(\Delta\theta)}{\Delta\omega}=\frac{d\delta}{\Delta\omega} \qquad (15)$$

Integrating, and substituting equation 14, finally gives:

$$t=\sqrt{\frac{G}{2}}\int_{\delta_0}^{\delta}\frac{d\delta}{\sqrt{\int_{\delta_0}^{\delta}P_a d\delta}} \qquad (16)$$

Evaluation of this integral gives angle as a function of time (implicit) which is the solution of the problem under consideration, being a "swing curve."

If analytical solution of this integral were practicable, graphical methods would be unnecessary. But analytical solution is possible in special cases only. One simple solution, which will be found useful as part of the graphical method, can be obtained by making the assumption that P_a is constant, and not a function of δ. Then

$$t=\sqrt{\frac{G}{2P_a}}\int_{\delta_0}^{\delta_1}\frac{d\delta}{\sqrt{\delta}}=\sqrt{\frac{2G(\delta_1-\delta_0)}{P_a}} \qquad (17)$$

But for general determination of swing curves the integrals of equation 16 are evaluated graphically.

APPLICATION OF METHOD

In applying the graphical method, one begins with the power-angle curve. Consider, specifically, a generator feeding an infinite bus through a transmission line. As a result of some disturbance of the system, such as the sudden occurrence of a fault on the transmission line, the power output of the generator becomes less than the power supplied to the generator by the prime mover. The power-angle curve of the system under transient conditions is shown in figure 1*a*; at each instant the angle δ and the power output P are related by the curve shown.

At the instant of the disturbance the angular position of the machine is known to be δ_o, so the power output of the machine immediately following the disturbance will be P_o.

The difference between the power output, P, and the power input, P_i (which is here assumed to be constant), is ΔP, and the vertical lines of shading may be interpreted as representing values of ΔP at different angular positions. Damping will be neglected in the present discussion, so ΔP will also be the accelerating power, P_a.

Area in the power-angle diagram represents the product of power and angle, and the shaded area is therefore the integral of equation 12. This area is next plotted, as in figure 1*b*. Area of the shaded part of figure 1*a* is measured (most readily by a planimeter), and beginning with zero area at δ_o one plots in figure 1*b* the accumulated area as one passes from left to right. Area below P_i is positive and that above P_i is negative. The accumulated area is designated A, as in figure 1*b*. The value of A at each value of δ in figure 1*b* is now multiplied by $2/G$ and the square root found; the result is plotted in figure 1*c*, which is a curve of the velocity of swing of the machine (see equation 14).

The next step is to plot the quantity $1/(\Delta\omega)$, as in figure 1*d*, taking reciprocals of values of curve 1*c* for each value of δ. Area under this curve, measured from left to right (again using a planimeter) and plotted as in figure 1*e*, is the required swing curve of the machine.

In practical computation it is not necessary that all these curves be drawn. Curve *b* may be omitted, and commonly (depending on whether damping and governor action are to be considered) curve *c* may be omitted also. If the power-angle curve is of such simple form (for example, sinusoidal) that the velocity of swing, $\Delta\omega$, can be found by ordinary integration in equation 14, curve *d* can be computed without the necessity of drawing curves *a*, *b*, and *c*, and graphical integration of curve *d* to obtain the swing curve *e* completes the solution.

In finding the area under curve *d*, difficulty is encountered in measuring area near the beginning and end of the swing. This is because the value of $1/(\Delta\omega)$ becomes large without limit as δ approaches δ_o, although the area under the curve is nevertheless finite. To avoid this difficulty it is safe to assume that during the first short interval of time the value of P_a does not vary from its value at the first instant. The time required for the machine to swing through some arbitrarily selected small angle to an angle δ_1 is then given by equation 17. For convenience, the solution of equation 17 is given graphically in figure 2. Its use is illustrated in the following example.

EXAMPLE

In this example the solution is carried out in its simplest form, assuming constant flux linkages and neglecting damping and variation of input power.

A generator feeds power to an infinite bus through two transmission lines in parallel; a three-phase fault occurs on one line which is automatically disconnected from the system after 0.20 second. (This is example III, page 427, reference 1.) The following information is given or is readily computed:

Power input, $P_i=0.80$ $\quad\delta_o=18.1$ degrees

Power-angle curves are (assume $x_d'=x_q'=x_q$):

During fault	$P=0.936\sin\delta$
After clearing	$P=2.06\sin\delta$

Inertia constant, $G=2.56\times10^{-4}$ seconds² per electrical degree.

Solution. Referring to figure 1, curves *a*, *b*, and *c* are not needed because A, and therefore $\Delta\omega$, are readily computed as follows. During fault:

$$P_a=P_i-P=0.80-0.936\sin\delta$$

$$A=\int_{18.1^\circ}^{\delta}P_a d\delta=0.80\delta+53.6\cos\delta-65.5$$

(δ is here integrated in degrees, not radians)

$$\frac{1}{\Delta\omega}=\sqrt{\frac{2.56\times10^{-4}}{2A}}$$

This is computed and the result is plotted as curve D in figure 3. Area to the left of this curve, the orientation being different from that of figure 1d, represents time. Area is measured and time is plotted as curve A, except that the first value of time, at 20 degrees, is obtained from figure 2 as follows:

$$\delta_1-\delta_0=20.0-18.1=1.9 \text{ degrees}$$

$$P_a \text{ at } 18.1 \text{ degrees}=0.509$$

$$\sqrt{\frac{G}{P_a}}=\sqrt{\frac{2.56\times10^{-4}}{0.509}}=0.022$$

Using this value to enter the chart of figure 2, and interpolating between diagonal lines for a swing of 1.9 degrees, one finds that the time required for this swing, and therefore the time required to reach an angular position of 20.0 degrees, is 0.042 second. This point is plotted as the first point on curve A, figure 3, and graphical integration is then used to determine other points on the curve until it is found that total elapsed time equals 0.20 second. This is the time at which the fault is cleared, and a different power-angle curve is thereafter used. It is found that when time=0.20 second, $\delta=51.0$ degrees, and $A=9.10$.

After clearing the fault:

$$P_a=0.80-2.06\sin\delta$$

Total area, including area before clearing the fault, is:

$$A=9.10+\int_{51.0^\circ}^{\delta}P_a\,d\delta=0.80\delta+118.2\cos\delta-106.2$$

Then $1/(\Delta\omega)$ is computed from the same formula as before, but using the revised value for A, and the results are plotted as curve E of figure 3. Graphical integration is then continued by measuring area to the left of this curve, and the resulting values of time are plotted as points on curve A. Graphical integration is impracticable beyond 60 degrees. It was found in computing A that it becomes zero at 61.0 degrees, and this establishes the angle of maximum swing. The chart of figure 2 is again used:

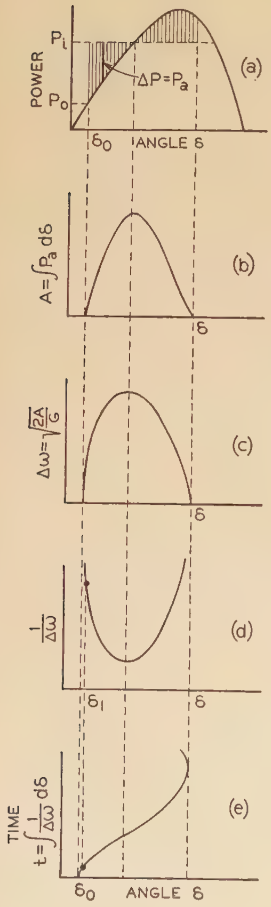
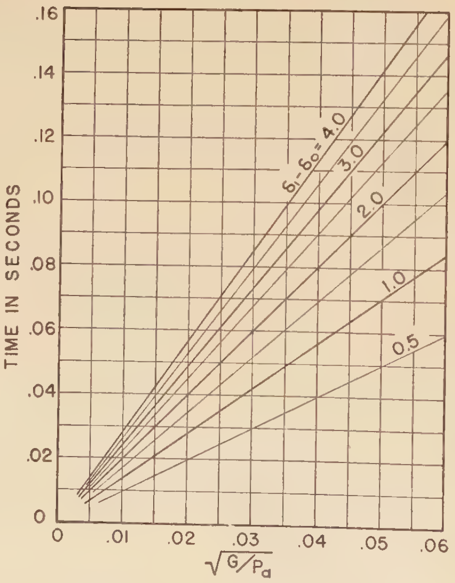


Figure 1 (left). Steps of a typical graphical solution

Figure 2



From 60.0 to 61.0 degrees, swing=1.0 degree

At (average) 60.5 degrees, $P_a=0.99$ and $\sqrt{G/P_a}=0.0161$

From figure 2, time to swing from 60.0 to 61.0 degrees=0.022 second

Since it was previously found that the time at 60.0 degrees was 0.252 second, addition gives the time at 61.0 degrees as 0.274 second. Beyond this time the curve is found by symmetry until the angle at which the fault was cleared is again reached. For later times the graphical method can be continued, using an extension of curve E, if desired.

Swing curves computed by the point-by-point method are included in figure 3 for comparison. The graphical solution is free from the cumulative error of the point-by-point solution which is particularly apparent in curve C, and the labor required is much less than for the point-by-point solution with short steps as illustrated by curve B.

NOTATION

A	area on power-angle curve sheet.
G	inertia constant.
I	moment of inertia.
P	power.
P_a	power used in accelerating the machine.
P_d	power absorbed in damping.
P_i	power input.
P_o	power output.
T_a	torque used in accelerating the machine.
t	time.
α	angular acceleration.
Δ	a symbol meaning "transient increment of."
ΔP	difference between power input and power output.
$\Delta\theta$	angle of transient swing from synchronous position.
$\Delta\omega$	angular velocity of transient swing.
δ	angle of swing from direct axis.

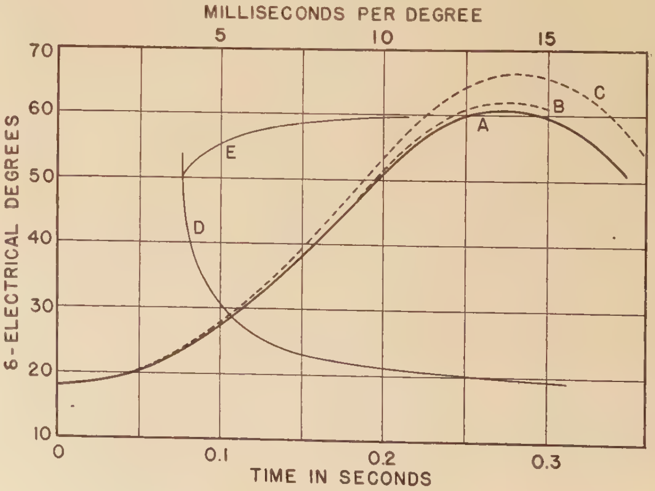
Figure 3. Example of computed swing curve

A—Computed by graphical method

B—Computed by point-by-point method using 0.01-second steps

C—Computed by point-by-point method using 0.05-second steps

D, E—Reciprocal-of-velocity curves (upper scale)



δ_0	steady value of δ preceding transient disturbance.
θ	angular position.
θ_s	synchronous angular position; that is, position the machine would have attained at synchronous speed had there been no transient disturbance.
ω	angular velocity.
ω_s	synchronous angular velocity.

UNITS

Any consistent system of units may of course be used, but the following is recommended:

Angle in electrical degrees.

Time in seconds.

Angular velocity in electrical degrees per second.

Power in fraction of rated power (per-unit system).

Area. For plotting figure 1*b*, unit ordinate corresponds to unit area on figure 1*a*. It is convenient to consider unit area a rectangle 10 electrical degrees by 0.1 (per unit) power. For plotting figure 1*e*, unit area on figure 1*d* represents one second. It is convenient to consider 0.01 second equivalent to a rectangle 10 electrical degrees by 0.001 on the reciprocal-of-velocity scale.

Inertia constant, G, in (seconds)^2 per electrical degree (this is the reciprocal of the unit of angular acceleration, and makes possible the simple formula: $\alpha = \Delta P/G$). The value of G is found from:

$$G = \frac{1.28I\,(\text{rpm})^2\,10^{-9}}{(\text{rated kva})(\text{frequency})} = \frac{H}{180\,(\text{frequency})} = \frac{M}{(\text{rated kva})}$$

where I is moment of inertia in (pound)(feet)^2 and M and H are different inertia constants from references 1 and 3, respectively.

CONCLUSION

A method of graphical computation of swing curves of synchronous machines under transient conditions has been outlined. Its theoretical basis is related to that of the "equal-area criterion" of transient stability. It gives angular position as a function of elapsed time, however, which is usually a necessary addition to the information obtained from the equal-area criterion.

The method is capable of taking into account system loads, losses, saliency of poles, damping, and other factors that are frequently decisive in stability studies. Its use is limited to systems to which power-angle curves are applicable. The method is relatively easy to use and is accurate.

REFERENCES

1. ELECTRIC POWER CIRCUITS, Volume II, O. G. C. Dahl. McGraw-Hill Book Company, Inc., New York, 1938.

2. SYMMETRICAL COMPONENTS, C. F. Wagner and R. D. Evans. McGraw-Hill Book Company, Inc., New York, 1933.

3. FIRST REPORT OF POWER SYSTEM STABILITY. AIEE TRANSACTIONS, volume 56, 1937, pages 261–82.

4. SYSTEM STABILITY AS A DESIGN PROBLEM, R. H. Park and E. H. Banker. AIEE TRANSACTIONS, volume 48, 1929, pages 170–94.

For other references see bibliography of reference 3.

Conowingo (Md.) dam and power plant on the Susquehanna River, which supplies a major portion of the power used in Philadelphia, Pa., is on the inspection-trips schedule of the AIEE winter convention to be held in that city January 27–31, 1941

Institute Activities

Middle Eastern District Sets Record With Cincinnati Meeting

THE Cincinnati Section was host to a very successful three-day meeting of the Middle Eastern District held October 9–11, with headquarters in Cincinnati's Netherland Plaza Hotel. With a verified registration of 599 members, guests, and students the meeting established a new high record for the District, and one exceeded only by District 3 at New York in 1926 (700), and by District 5 at Chicago in 1927 (900) and in 1929 (600) among the 42 Institute District meetings that have been held since they were inaugurated in 1924.

GENERAL MEETING

The meeting was opened by E. S. Fields, chairman of the general committee who introduced C. T. Sinclair, vice-president for the Middle Eastern District. Vice-President Sinclair complimented Chairman Fields and his committee for the excellence of the program, and President Sorensen spoke briefly. A most cordial welcome to the meeting was extended by Mayor James Garfield Stewart of Cincinnati. The Mayor gave a good insight into the early history and traditions of the city as well as its friendly community spirit and said that it was "fine to have here men who have the American ways of doing things and that made one optimistic for the future....I am delighted to see competitive people get together and work out their problems cooperatively in a friendly manner."

MEETING LUNCHEON

The meeting luncheon was held on Thursday, October 10, in the Pavilion Caprice Terrace. Vice-President Sinclair expressed his personal gratification for the large attendance and commented on the high quality of the papers and discussions. President Sorensen addressed the luncheon meeting briefly concerning some of the broader aspects of engineering in relation to preparedness and the public at large. He referred to the inventions of the cotton gin, the harvester, the automobile, and the radio, emphasizing that industry is the real backbone of preparedness and that engineers long have been intimately associated with the development of industry. President Sorensen urged engineers to "stretch outside of the professional societies a bit more and get into civic and community activities, such as the Chamber of Commerce, etc., in order to become better acquainted with people from other walks of life." Thus engineers would be in a better position to help in the solution of problems having social implications.

STUDENT ACTIVITIES

In the opinion of those responsible for student activities at the Cincinnati meeting, the student attendance and participation "was the outstanding feature in view of the distances involved in traveling to Cincinnati." Of the 22 student branches in the District, the registration included representatives from 18, 17 of them outside of Cincinnati. In addition to the Enrolled Students affiliated with the Institute, many other engineering students are reported as being in attendance, appearing in the registration figures as men guests.

There was no technical program of student papers, as the branches in the District had voted against such a program last spring. However, the items of interest in the regular program of technical sessions were described as being so diverse in character and so numerous in quantity that the students were very well served and were outspoken in their praise. There were special inspection trips and entertainment for students, and free transportation for trips to a steel mill and a rolling mill. Also, students participated in the regular inspection trips.

Analysis of Registration at Cincinnati

Classification	Location Cincinnati Section	 District 2*	 Other Districts	Totals
Members	97	105	79	281
Enrolled Students	31	48	4	83
Men Guests	113	38	32	183
Women Guests	24	19	9	52
Totals	265	210	124	599

* Outside Cincinnati.

The meeting of Student Branch counselors, with Chairman L. R. Culver of the District's committee on student activities presiding, was held at 10 o'clock Thursday morning, October 10, with 18 of the District's 22 student branches represented. Invited guest speakers were Professor H. W. Bibber and Doctor F. C. Caldwell, both of Ohio State University, Columbus. The business session of the conference was devoted primarily to consideration of the question of District prize papers and related awards. The counselors completed their two-year study of this subject, and forwarded their recommendations to the District executive committee. The counselors concluded their session by selecting the University of Maryland for next year's conference, and electing Professor H. S. Bueche (Villanova) as chairman of the District committee on student activities for the ensuing period.

In parallel with the counselors' meeting, the student officers group held a meeting with Chairman John P. Quitter of the University of Cincinnati Branch presiding. This group consisted of 25 people from 18 schools. Pursuant to a review of recent experience, and a general discussion of the topic, the branch officers decided to continue for the coming year the Middle Eastern District "Student News-Sheet" which was started in 1939. On the strength of its fine performance of last year, the Case School of Applied Science Branch was successfully prevailed upon to continue as publishing agent for the ensuing year. All Branches will contribute news items, and each Branch will receive four copies of each issue at a yearly cost of $2.00 per Branch.

At noon the students and counselors luncheon was held and the gathering was addressed by Vice-President C. T. Sinclair.

DISTRICT EXECUTIVE COMMITTEE MEETING

The annual meeting of the Middle Eastern District's executive committee was held at 2:00 p.m., Thursday, October 10. Among the items of business it was decided to hold the next meeting of the Middle Eastern District at Pittsburgh in 1942. W. B. Morton, secretary of Philadelphia Section and vice-chairman of the 1941 winter convention committee, was chosen as the District's delegate to the national nominating committee.

ENTERTAINMENT AND TRIPS

The informal dinner was held in the Pavilion Caprice at the Netherland Plaza Hotel on Thursday evening, October 10, with music and dancing between courses. Members and guests were entertained with stories told by President Sorensen resulting from his experiences while traveling east from California by train. An entertaining and instructive satire on the subject of "The Passion for Painless Education" was given by Doctor Frank W. Chandler, professor of English at the University of Cincinnati. The talk was humorously exemplified by typical magazine advertisements. Professor A.M.Wilson acted as toastmaster. After the talks guests were entertained with excellent musical and dancing acts.

A smoker and buffet dinner were held in the ballroom of the Hotel Metropole on Wednesday evening. Following the dinner,

Middle Eastern District Meeting Attendance 1925–40

Date	Location	Attendance
1940—Oct. 9–11	Cincinnati, Ohio	599
1939—Oct. 11–13	Scranton, Pa.	313
1937—Oct. 13–15	Akron, Ohio	464
1932—Oct. 10–13	Baltimore, Md.	240
1931—Mar. 11–13	Pittsburgh, Pa.	500
1930—Oct. 13–15	Philadelphia, Pa.	500
1929—Mar. 20–23	Cincinnati, Ohio	270
1928—Apr. 17–20	Baltimore, Md.	400
1927—Apr. 21–23	Bethlehem, Pa.	400
1926—Mar. 18–19	Cleveland, Ohio	430
1925—Jan. 23–24	Washington, D. C.	212

entertainment and smokes were offered. Thursday afternoon a number of the people attending the meeting took advantage of the popular trip to the Newport Rolling Mills and to the Andrews Steel Company at Newport, Kentucky, as well as the alternate sightseeing tour of Cincinnati and its environs. Those taking the latter trip enjoyed the privilege of visiting the new central fire signal control station of the Cincinnati Fire Department. These trips were also repeated on Friday afternoon, at which time there were other trips to the studios and transmitter of Station WLW and the Crosley Television Station as well as the Columbia Station of the Cincinnati Gas and Electric Company. During the meeting women guests were entertained by a series of special events including a bridge-luncheon, a shopping and sightseeing tour, a visit to a radio studio to witness the broadcasting of a national feature program. Trips were taken to nearby industries, and to the Charles Phelps Taft Museum where a musicale and tea were enjoyed.

TECHNICAL SESSIONS

Parallel technical sessions held on each of the three days during the meeting were well attended and offered a variety of subject matter. The session on aviation, instruments and control, as well as the session on industrial power applications and the conference on protective lighting, were considered as initial steps to acquaint engineers with some of the problems of national defense. The papers were presented by officers in the United States Army Air Corps, as well as by men in industries co-operating in the defense program. The session on aviation, instruments and control was presided over by E. E. Minor, Baltimore, chairman of the Institute's newly-formed committee on air transportation. Chairmen for the other sessions were: C. F. Lee, Cincinnati, general; E. W. Oesterreich, Pittsburgh, power transmission and distribution; C. M. Gilt, New York, electrical machinery; J. J. Orr, New York, industrial power applications; O. P. Cleaver, Bloomfield, N. J., conference on protective lighting; E. E. Dreese, Columbus, Ohio, selected subjects; J. L. Hamilton, St. Louis, Mo., session on single-phase motors and conference on motors and applications. Attendance at the nine technical sessions and conferences ranged from 55 to some 240, averaging about 115.

Conferences on Lighting and Motors Held in Cincinnati at District Meeting

Two technical conferences were held as a part of the regular program of the Middle Eastern District meeting held in Cincinnati, Ohio, October 9–11, 1940. High lights of these conferences are reflected in the following items as reported by Chairman O. P. Cleaver of the Conference on Protective Lighting, and by Chairman J. L. Hamilton of the Conference on Motors and Applications.

Conference on Protective Lighting

This conference was organized for the purpose of discussing the need and the present-day methods of lighting industrial plants as a protective measure against espionage and sabotage. Four informal papers were given followed by considerable discussion from the audience.

In the first paper, by Mr. Suran of the Federal Bureau of Investigation, it was pointed out that the need for protective lighting has increased greatly in the last few months. The FBI has been appointed by the President of the United States to undertake all matters pertaining to sabotage and similar "Fifth Column" activities. Already, the special agents of this Department have investigated many important factories and where necessary have recommended protective lighting along with other types of protection.

It was pointed out that the FBI had no authority to force plant officials to install protective lighting, nor did they set up standards to govern the extent of this lighting and the methods used. Their function is solely to advise of the need for this type of protection.

A significant point was made by Mr. Suran to the effect that it was advisable to have sufficient outdoor and indoor lighting to enable guards not only to see the intruder but to recognize him as well. Since present protective lighting standards are far below that needed for actual recognition, it was evident that changes would have to be made in standards if this program were carried out. The questions following Mr. Suran's talk brought out the fact that lighting is essential, especially in factories where guard forces are inadequate. It was stated that adequate lighting might be considered to take the place of guards if an adequate protective guard force was prohibitive in cost.

Elaborating more specifically on the need for protective lighting, Mr. Summers, the next speaker, pointed out that two problems were involved: (1) protective lighting before invasion of the premises; and (2) protective lighting after invasion. In the first case, as much light as possible is an advantage. In the second instance, as little light as possible can be an advantage. Light in itself cannot keep the saboteur out, according to Mr. Summers, but will keep out the minor criminals and cranks.

According to Mr. Summers, guards should not be kept in the dark unless placed on the roof where they have a certain measure of safety and yet can survey the entire property. Glare is an important protection factor for guards when properly used. If floodlights are directed toward a possible intruder, the glare will serve to blind him and obscure the guard. Shadows are dangerous and should be avoided in any type of protective lighting.

The following elements of a plant need particular study in designing protective lighting:

1. An adequate fence around the property should never be omitted as a protective element. It should be painted white or have a light background.
2. Dark alleys should be well lighted, particularly if near railroads or highways.
3. Parked railway cars should be well lighted, for they are good places for saboteurs to hide.
4. All entrances and exits should be lighted whether used at nighttime or not.
5. Accessible roofs, where intruders might possibly jump from another building outside on to the property should be protected.
6. Dead-end streets and blind approaches should be kept in mind.
7. Wharves and approaches from water require special attention.
8. Generating stations should not be floodlighted, but should have light surrounding the station. Floodlighting of important buildings, such as this, draws attention to their importance, Mr. Summers pointed out.

The use of dogs as a supplement to lighting was stressed several times during the conference. It was pointed out that they are very effective in searching out intruders and are an inexpensive method of protection.

The next speaker, Mr. Steiner, discussed more in detail the types of lighting available to meet protective lighting specifications. On a large pictorial representation of a typical factory and surrounding area, he pointed out that the boundaries should be given first attention. Two methods for lighting the boundaries were discussed:

First, the use of floodlights with spread lenses mounted two to a group, placed on the inside of the property and directed outward. This method uses glare as a hindrance to a possible intruder.

The second method is to mount floodlights along the fence on poles or structures near the fence. The speaker preferred the method of lighting in two directions from each pole, rather than a uni-directional method. Poles should be from 25 to 30 feet high and spaced some 300 feet apart, with 500-watt narrow-beam floodlights for the best results. He pointed out that a less expensive and yet effective method is the use of street-lighting types of units suspended from poles about 25 feet from the ground. For this purpose, 300- to 500-watt lamps on 75- to 125-foot spacing were recommended.

Unfenced boundaries such as docks and water approaches also should be given consideration. Floodlights with spread lenses, set back and aimed out over the water, seem to be the best method suggested to date.

Two types of entrances to a plant were emphasized by Mr. Steiner: (1) authorized entrances where the lighting should be sufficient to recognize anyone passing through or approaching; (2) unauthorized entrances, such as a railroad track or a stream running through the property. The latter type should be very carefully illuminated in a manner to prevent dense shadows where intruders may easily conceal themselves.

On the inside of the boundary, the lighting must be of such a nature as not to spotlight power houses, office buildings, storage tanks, etc., but rather to light the area around them. Floodlighting was recommended. Poles located on the grounds or mountings along the tops of buildings seem to provide the most favorable locations for such floodlights. Wherever possible, a band of light around a building, directed in such a manner that the glare from the lighting units would work to the disadvantage of an intruder and to the advantage of any guard, is the most desirable kind.

In addition to general area lighting and boundary lighting, it is important that a separate system of emergency lighting be available in case power supply lines are cut or otherwise destroyed. This system could be portable or housed in a special tower containing manually-operated searchlights, so mounted that they could be directed to any spot on the factory grounds that might be in danger from saboteurs. Gasoline-engine-driven generating plants were preferred, although storage batteries might possibly be used for such an emergency system.

The last paper of the afternoon was by Mr. Dana, who discussed the various types of floodlights available for protective lighting purposes. He illustrated his talk by demonstrating types of equipment now available.

In addition, he discussed types of circuits and controls for protective lighting, favoring the multiple circuit controlled locally by a manual switch as being generally the most economical. Time switches and photoelectric controls are serviceable, but more expensive. In boundary lighting, however, the series circuit with constant-current transformers seems to be the most serviceable type of distribution. He pointed out that the tendency today is to replace the old metallic type of cable with cheaper rubber-insulated cable covered with a very tough coating.

Types of light sources also were discussed briefly as to their relative merit and cost, with the incandescent lamp being the favorite at present because of its inexpensiveness and serviceability. It was pointed out that high-intensity mercury lamps require some time to relight after a circuit is disturbed when the lamp is hot and, furthermore are rather sensitive to voltage variations. The sodium lamp has possibilities, but it also has the time-lag factor to overcome in starting, and the extended light-source made reflector control less accurate.

Following the papers, there was considerable discussion from the audience. Emphasis was given to the necessity for easy maintenance and quick replacement of lamps and fixtures when injured. Cost figures were given to show the comparative cost of a specific installation of protective lighting, using incandescent, sodium, and high-intensity mercury vapor lamps. The incandescent lamp proved to be the least expensive, provided current rates were less than one cent per kilowatt-hour.

Conference on Motors and Applications

This conference was held Friday afternoon, October 11. The fore part of the conference session was devoted to a continuation of the discussion of the seven technical papers presented at the Friday morning regular technical session on the general subject of single-phase motors. Subsequently E. L. Splitstone, chief engineer of the Emerson Electric and Manufacturing Company, St. Louis, Mo., presented an informal paper concerning "Uses and Abuses of Thermal Protectors." Speaking concerning the application rather than the types or construction of such devices, Mr. Splitstone pointed out that a protection device actuated only by current is not entirely adequate for small motors, especially motors of the induction type. Such motors normally have starting currents quite high in comparison with their full load current. Hence, if the fuse, breaker, or relay, even though of the time-element type, has sufficient capacity to permit starting under load conditions, it probably will permit continuous overloading sufficient to overheat or burn out the running windings. The speaker considered that the inherent overheating protector appears to be the answer to this problem, but that it is in danger of being condemned or at least of having its use restricted because of misuse or improper application. The speaker therefore considered that it was desirable for the motor manufacturing industry to join in giving the problem the attention required to assure that the advantages of the thermal protector may be preserved to the industry and to assure that its use will not be condemned because of improper application or usage.

The discussion, in general, agreed with the thoughts expressed in Mr. Splitstone's paper and all felt that while the inherent thermal protectors are proving very beneficial, especially in the protection of small motors, there are opportunities for the abuse of motors through the use of inherent protectors under some conditions of operation, and that all must co-operate in safeguarding the interests of both the motor manufacturer and the user.

Mr. Hough of the Reliance Electric & Manufacturing Company, Cleveland, then presented an informal paper entitled, "Recent Developments in Magnet Wire." Mr. Hough gave the result of extensive research on new developments in magnet wire, including wire coated with nylon, formex, and formvar, as well as the conventional enamel and cotton coverings. Mr. Hough pointed out that these new magnet-wire insulating materials are being used to an appreciable extent; that the quality of these new materials is improving, and the knowledge and ability of the manufacturer to apply the insulation and use the materials also is improving.

He cautioned against the industry proceeding too rapidly in the use of these new materials. An interesting and informal discussion by several of those present indicated that, in the main, all were in agreement with the conclusions reached by Mr. Hough.

National • • • •

Plans Progressing for Winter Convention in Philadelphia

Plans have been under way for nearly a year for the forthcoming 1941 winter convention in Philadelphia, Pa., January 27–31, 1941. The "Quaker City" with its numerous industries of a highly diversified nature and its historical background offers many attractions for visitors. Full advantage of these features will be taken by the winter convention committee in making arrangements for the meeting. Tentative plans call for a larger number of technical sessions than heretofore and for some of the inspection trips and sessions to be co-ordinated. Convention headquarters will be in the Bellevue-Stratford Hotel.

TECHNICAL SESSIONS

Technical sessions in the following fields of activity have been tentatively scheduled to include: standards $1^1/_2$, instruments and measurements 1, electrochemistry and electrometallurgy 1, power generation 2, communication 2, electrical machinery 2, basic sciences 1, land transportation 2, power transmission and distribution 2, joint power transmission and protective devices 1, protective devices 2, electronics 1, and industrial power applications 1.

Arrangements also have been made for several technical conferences including: standards, instruments and measurements, electrochemistry and electrometallurgy, communication, basic sciences, electronics, production and application of light, industrial power applications, and air transportation.

CONVENTION COMMITTEE

The personnel of the 1941 winter convention committee, who are making arrangements for the convention to be held in Philadelphia, is as follows: N. E. Funk, chairman; W. B. Morton, vice-chairman; I. M. Stein, treasurer; J. W. Barker, J. V. B. Duer, C. R. Freehafer, L. M. Goldsmith, E. W. Loomis, H. Pender, H. S. Phelps, D. C. Prince, F. W. Shackelford, J. B. Harris, Jr., J. H. Tracy, and R. W. Wilbraham. The chairmen of subcommittees are: R. W. Wilbraham, dinner-dance; I. M. Stein, finance; H. S. Phelps, hotel, meetings, signs, and printing; A. G. Kisner, inspection trips and transportation; Mrs. D. C. Prince, women's activities; D. C. Prince, medal presentation; H. C. Albrecht, publicity and sponsor for women's committee; E. P. Yerkes, registration, information, and reception; J. B. Harris, Jr., smoker and special events; C. D. Fawcett, student activities.

Conferences on Load Swings at Summer, Pacific Coast Conventions

One of the technical conferences held at the 1940 summer convention at Swampscott, Mass., June 24–28, 1940, was on the subject of load swings. Another conference on the subject was held during the Pacific Coast convention at Los Angeles, Calif., August 27–30, 1940, the second conference being in part a repetition of the first. Both are covered in the following report, which was prepared by E. C. M. Stahl, member (chairman 1938–40) of the committee on power generation. Reports of the other technical conferences held during the summer convention appeared in the August issue, pages 337–40.

Considerable attention has been focused on the subject of load swings, turbine-generator governing, and stability, not only when a system is operated alone, but also when it is interconnected with other systems. Because of the widespread interest in this subject and the need of extensive investigation for the ultimate solution of the many problems involved, it was deemed desirable to schedule a conference at which informal discussion would be possible in advance of the preparation and presentation of formal papers before the Institute. The objective of the conference held at Swampscott, Mass., June 25, 1940, was the crystallization of the problem with particular reference to the functional requirements and limitations of a prime-mover speed governor.

J. B. McClure of the General Electric Company outlined the requirements of governing mechanisms with respect to their being essential, necessary, and desirable. The functions discussed included dead band, uniform incremental regulation, adjustable regulation, similarity in rate of response, accuracy of response for supplemental adjustment, and indications of all adjustments.

A. C. Monteith of the Westinghouse Electric and Manufacturing Company discussed the problem of power-system governing from the viewpoint of the operating engineer as gathered from the answers to a questionnaire to which 20 representative operating companies responded. The general conclusions seem to indicate that there are no outstanding deficiencies in modern governing systems. It seems likely that full advantage is not being utilized of the inherent capabilities of many existing governors. A test program is required to disclose maintenance defects, wrong adjustments, and improper operation. The limitations of the speed governor for interconnected operation must be recognized, and means provided to supplement the governor when close control of frequency or tie-line load is required.

A. P. Hayward of the Duquesne Light Company discussed the simple speed governor with respect to its limitations, requirement of auxiliary equipment to assist it in controlling load, and operating difficulties. From the standpoint of application, the factors needing additional consideration are:

1. Means of adjusting the speed regulation both for steady-state and transient conditions to permit co-ordination of the newer governors with the older governors.
2. Further reduction in the incremental regulation from minimum to maximum load and the elimination of dead spots.
3. Improvements in the speed-changer mechanism to provide the required sensitivity and uniform response.
4. Provision for decreasing the sensitivity of the governor within the continuous maneuvering range.

J. E. McCormack of the Consolidated Edison Company, Inc., of New York discussed the results of a series of tests made to determine the magnitude and period of load swings on the system with a view toward establishing the initiating cause or causes and the effect that the various system-regulating devices had in correcting or amplifying these swings. The general conclusion from these tests is that swings of reasonably large magnitude are caused by manual regulating operations in transferring load from one part of the system to another, or by incorrect anticipation of load changes, rather than by any factor inherent in the system load or regulation equipment. In order to minimize these, frequency indicators with a common reference are being installed in the major stations, so that the turbine throttles will be operated to increase or decrease load in such a way that load will be picked up by a station only on decreasing frequency and dropped off only on rising frequency.

An instrument for recording governor characteristics was described by F. Oppenheimer of the Pennsylvania Water and Power Company. The instrument simultaneously records, on a chart $3^1/_2$ inches wide, frequency and gate opening or valve position against time, and gate opening against frequency for the corresponding interval of time, from which the inherent speed droop can be determined as a function of the load on the machine.

Additional discussion centered upon problems encountered by various systems. The need of standardizing terms and tests to determine whether or not governors meet guaranteed performance was emphasized. The conference was fortunate in having the attendance of Professor C. R. Soderberg of Massachusetts Institute of Technology who, as chairman of committee number 20 of The American Society of Mechanical Engineers power test code, described the activities of his committee in preparing a code for speed-sensitive elements. An invitation for the co-operation of the AIEE committee on power generation was accepted.

The conference held at Los Angeles, Calif., August 28, 1940, supplemented the one held at Swampscott. Three prepared reports were presented, two of which also had been presented at Swampscott by Messrs. McClure, Monteith, and Hayward. The third report, presented by T. E. Curtis of the Pacific Gas and Electric Company, described a new electronic control system with which a standard flyball governor may be made sensitive to both frequency and load by means of a balanced solenoid that actuates the pilot valve. The proposed control system has yet to stand the test of operating experience, although the essential operation of the controller has been verified in the laboratory under conditions of an artificial power system.

The general discussion that followed the presentation of the written reports disclosed that the operating problems of the western and Pacific Coast systems are not materially different from those discussed at the Swampscott conference by the representatives of eastern systems. Greater interest was shown, however, in the control of hydro turbines and in the reduction of time lag between pilot-valve action and gate movement.

An attendance of 100 at the Swampscott conference and 42 at the Los Angeles conference indicates the timeliness and importance of, and the interest in the subject. It is believed that the purpose of these conferences has been fulfilled, and the indications are that an interesting program on the subject will be provided for the 1941 winter convention.

Supplement Name Changed; Procedure Explained

In order that its name might indicate more accurately the nature of its content, the name of the Supplement was changed by action of the AIEE publication committee, at its October 2, 1940, meeting, to "Supplement to Electrical Engineering—Transactions Section." As the new name implies, and as has been announced previously, the Supplement contains material which "supplements" the monthly Transactions sections of Electrical Engineering, comprising those technical-program papers and discussions published in the current annual bound volume of the Transactions, but not included in the 12 monthly sections. Thus, a member may receive *all* technical papers and discussions published by the Institute during the year by adding the Supplement to his 12 monthly issues of Electrical Engineering.

Future AIEE Meetings

Winter Convention
Philadelphia, Pa., January 27–31, 1941

Great Lakes District Meeting
Fort Wayne, Ind., April 1941

North Eastern District Meeting
Rochester, N. Y., April 30–May 2, 1941

Summer Convention
Toronto, Can., June 16–20, 1941

Pacific Coast Convention
Yellowstone National Park, August 27–29, 1941

Continuing on the annual basis originally established in 1938, an annual Supplement for 1940 will be issued during December. Under the provisions of the recently adopted changes in publication policy, however, the Supplement is scheduled to be issued semiannually—June and December—beginning with 1941 (*EE, Aug. '40, p. 331–2*). As announced in the October issue (*p. 413–20*) the 1940 Supplement will contain nearly 600 pages, instead of a normal of about 350 pages. This enlargement will absorb part of the large backlog of material awaiting publication built up by certain requirements of the previous publication policy and will constitute a major step toward the realization of one of the major goals of the new policy—much earlier publication of technical papers and discussions. Likewise, as a further necessary step in the transition from the former to the new publication policies, both of the semiannual Supplements for 1941 will contain an abnormally large number of pages. In spite of the enlarged content, the price of the Supplement will be maintained at 50 cents per copy for both 1940 and 1941 to members in the United States and possessions, instead of $1.00 as indicated in the October issue for the 1940 Supplement. The price to members in Canada and all other countries will be $1.00 per copy to cover extra mailing costs.

The new publication policies also are having a marked effect on the content of the monthly Transactions sections of Electrical Engineering. To enable the publication date of Transactions material to be advanced as called for in the new policy, and to accomplish the correspondingly increased rate of publishing that material as required to absorb the aforementioned backlog within a nominal period of time *and* without adding heavily to the publication budget requirements, the total number of pages in the Transactions sections of Electrical Engineering has been reduced by approximately the average number of pages previously devoted to discussions. By immediate adherence to the new policy provision which gives preference to papers of six or less pages for the monthly sections—leaving the longer papers for publication in the annual volume—it is expected that members will continue to receive in Electrical Engineering during the transition period just about as many technical papers on the average as they have been receiving through that channel during recent years. After the transition has been completed—hopefully by the end of 1941—

members may expect to receive through Electrical Engineering under the new publication policy a markedly increased number and proportion of technical papers. Readers and authors are warned, however, that, until the necessary transition from the former to the new publication policy is completed, the total number of papers of six or less pages may be too great for all such papers to be included in the temporarily reduced monthly Transactions sections of Electrical Engineering. In such an event, however, the rule of preference for the shorter papers still will apply.

Additional Committee Personnel

A complete list of the Institute's officers and committees for 1940–41 was published in the September issue, pages 377–81, with the exception of the general committee on transfers, and the technical committees on industrial power applications, electric welding, air transportation, and land transportation. The membership of these committees has now been completed and is listed here.

Transfers

F. O. McMillan, *chairman*, Oregon State College, Corvallis, Ore.

F. M. Craft
H. C. Don Carlos
Harold Goodwin, Jr.
G. A. Kositzky
E. L. Moreland
D. C. Prince

Air Transportation

E. E. Minor, *chairman*, The Glenn L. Martin Company, Baltimore, Md.

H. A. Campbell
W. J. Clardy
F. M. Defandorf
J. H. Gardner
V. H. Grant
E. E. Johnson
J. P. Maxfield
D. C. Prince
Mrs. M. M. Rockwell

Electric Welding

J. D. Wright, *chairman*, General Electric Company, Schenectady, N. Y.

J. H. Blankenbuehler
L. W. Clark
W. E. Crawford
J. W. Dawson
Wray Dudley
D. D. Ewing
G. W. Garman
K. L. Hansen
C. E. Heitman, Jr.
W. F. Hess
S. M. Humphrey
J. H. Lampe
G. G. Landis
C. I. MacGuffie
F. W. Maxstadt
C. L. Pfeiffer
C. A. Powel
E. H. Vedder

Industrial Power Applications

J. J. Orr, *chairman*, United States Rubber Company, 1230 Sixth Ave., New York, N. Y.

E. A. Armstrong
T. F. Barton
E. T. Carlson
R. F. Chamberlain
C. W. Drake
J. H. Edwards
E. Gordon Fox
John Grotzinger
F. E. Harrell
A. E. Knowlton
E. D. Lilja
M. J. McHenry
F. C. Nicholson
W. A. Perry
D. E. Renshaw
H. W. Rogers
F. O. Schnure
H. L. Smith
Herbert Speight
L. A. Umansky
E. V. Valk
R. L. Walsh
B. M. Werly
J. D. Wright
R. H. Wright

Land Transportation

E. B. Fitzgerald, *chairman*, The American Car and Foundry Company, Berwick, Pa.

R. Beeuwkes
L. W. Birch
G. E. Bishop
W. A. Brecht
J. C. Davidson
C. M. Davis
E. G. Davis
J. V. B. Duer
D. D. Ewing
J. E. Gardner
Selby Haar
J. S. Hagan
W. S. H. Hamilton
P. H. Hatch
G. L. Hoard
Fraser Jeffrey
L. C. Josephs
F. C. Lindvall
P. A. McGee
R. J. Needham
R. J. Parsons
W. I. Slichter
Dwight L. Smith
L. J. Turley
W. M. Vandersluis

Nomination of AIEE Officers for 1941 Election

For the nomination of national officers to be voted upon in the spring of 1941, the AIEE national nominating committee will meet during the winter convention, January 27–31, 1941. The officers to be elected are: a president, a national treasurer, three directors, and five vice-presidents, one from each of the even-numbered geographical Districts. Fellows only are eligible for the office of president, and Members and Fellows for the offices of vice-president, director, and national treasurer.

To guide this committee in performing its constituted task, suggestions from the membership are, of course, highly desirable. To be available for the consideration of the committee all such suggestions must be received by the secretary of the committee at Institute headquarters, not later than December 15, 1940.

In accordance with the provisions in the constitution and bylaws, as amended during 1935 and quoted in the following paragraphs, actions relative to the organization of the national nominating committee are now under way.

Constitution

28. There shall be constituted each year a national nominating committee consisting of one representative of each geographical district, elected by its executive committee, and other members chosen by and from the board of directors not exceeding in number the number of geographical districts; all to be selected when and as provided in the bylaws. The national secretary of the Institute shall be the secretary of the national nominating committee, without voting power.

29. The executive committee of each geographical district shall act as a nominating committee of the candidate for election as vice-president of that district, or for filling a vacancy in such office for an unexpired term, whenever a vacancy occurs.

30. The national nominating committee shall receive such suggestions and proposals as any member or group of members may desire to offer, such suggestions being sent to the secretary of the committee.

The national nominating committee shall name on or before January 31 of each year, one or more candidates for president, national treasurer, and the proper number of directors, and shall include in its ticket such candidates for vice-presidents as have been named by the nominating committees of the respective geographical districts, if received by the national nominating committee when and as provided in the bylaws; otherwise the national nominating committee shall nominate one or more candidates for vice-president(s) from the district(s) concerned.

Bylaws

Sec. 22. During September of each year, the secretary of the national nominating committee shall notify the chairman of the executive committee of each geographical district that by December 15 of that year the executive committee of each district must select a member of that district to serve as a member of the national nominating committee and shall, by December 15, notify the secretary of the national nominating committee of the name of the member selected.

During September of each year, the secretary of the national nominating committee shall notify the chairman of the executive committee of each geographical district in which there is or will be during the year a vacancy in the office of vice-president, that by December 15 of that year a nomination for a vice-president from that district, made by the district executive committee, must be in the hands of the secretary of the national nominating committee.

Between October 1 and December 15 of each year, the board of directors shall choose 5 of its members to serve on the national nominating committee and shall notify the secretary of that committee of the names so selected, and shall also notify the 5 members selected.

The secretary of the national nominating committee shall give the 15 members so selected not less than 10 days' notice of the first meeting of the committee, which shall be held not later than January 31. At this meeting, the committee shall elect a chairman and shall proceed to make up a ticket of nominees for the offices to be filled at the next election. All suggestions to be considered by the national nominating committee must be received by the secretary of the committee by December 15. The nominations as made by the national nominating committee shall be published in the March issue of Electrical Engineering (Journal of AIEE), or otherwise mailed to the Institute membership not later than the first week in March.

INDEPENDENT NOMINATIONS

Independent nominations may be made in accordance with provisions in Section 31 of the constitution and Section 23 of the bylaws, which are quoted herewith:

Constitution

31. Independent nominations may be made by a petition of twenty-five (25) or more members sent to the national secretary when and as provided in the by-laws; such petitions for the nomination of vice-presidents shall be signed only by members within the district concerned.

Bylaws

Sec. 23. Petitions proposing the names of candidates as independent nominations for the various offices to be filled at the ensuing election, in accordance with Article VI, Section 31 (constitution) must be received by the secretary of the national nominating committee not later than March 25th of each year, to be placed before that committee for

---

New Members

Mr. Institute Member:

A continuous inward flow of new members is as essential to the Institute as are new cells to the body, and they serve the same purpose, namely, to replace natural losses and provide for growth.

The volunteer workers of Section membership committees will do all they can to locate and interview eligible prospects, but their numbers are few and their scope of contact limited. Success will attend their efforts only if they receive the co-operation and assistance of all members.

Send them the names of any eligible prospects that you know of, or, better still, try to interest the prospects yourself as it may be more difficult for the committee members to reach them.

O. C. Brill

Chairman, National Membership Committee

the inclusion in the ballot of such candidates as are eligible.

On the ballot prepared by the national nominating committee in accordance with Article VI of the constitution and sent by the national secretary to all qualified voters during the first week in April of each year, the names of the candidates shall be grouped alphabetically under the name of the office for which each is a candidate.

(*Signed*) H. H. Henline,
National Secretary

November 1, 1940

Personal • • •

Alexander Maxwell (F'37) director of engineering, Edison Electric Institute, New York, N. Y., has been appointed chairman of the newly created AIEE committee on domestic and commercial applications for 1940–41. He was born at New York, N. Y., May 13, 1878, and educated there. In 1894 he became an assistant in the laboratory and testing departments of the Westinghouse Electric and Manufacturing Company at Newark, N. J., and the following year entered the employ of the Manhattan Electric Light Company, New York, N. Y., as assistant to the electrical engineer. He continued in that position with the New York Edison Company after 1899. From 1912 to 1917 he was director of the general laboratory of the New York Edison Company. During the next two years he was in active service with the United States Army, attaining the rank of major, and later becoming a lieutenant-colonel in the Reserve Corps. He returned to the New York Edison Company in 1919 as engineer on stray current electrolysis and inductive co-ordination of power and communication circuits, and from 1921 to 1923 was engineer of distribution, redesigning d-c distribution system. He became an engineer with the National Electric Light Association, New York, in 1923, on inductive co-ordination, power and communication circuits, and later on research and administrative work. Except for a half year at the United States Army Command and General Staff School in 1925, he continued with NELA until the organization was dissolved and succeeded by the Edison Electric Institute. He was made director of engineering of the latter on its formation in 1933 and has continued in that position since. He is also a member of the AIEE board of examiners.

ALEXANDER MAXWELL

J. R. NORTH

C. M. GILT

F. B. Jewett (A'03, F'12) vice-president, American Telephone and Telegraph Company, New York, N. Y., has resigned as president of Bell Telephone Laboratories and becomes chairman of the board of directors. The change will increase the time he has available in an advisory capacity to the Government as president of the National Academy of Sciences and as a member of the National Defense Research Committee. He was born at Pasadena, Calif., September 5, 1879, and received the degree of bachelor of arts from Throop Technological Institute (now California Institute of Technology) in 1898, and that of doctor of philosophy from the University of Chicago in 1902. He was an assistant in physics at the University of Chicago, Chicago, Ill., 1901–02, and in physics and electrical engineering at Massachusetts Institute of Technology, Cambridge, 1902–04. He went with the American Telephone and Telegraph Company in 1904 as a transmission engineer. In 1912 he became assistant chief engineer of the Western Electric Company, in 1916 chief engineer, and in 1922 vice-president. He was made vice-president in charge of research and development of the American Telephone and Telegraph Company and president of Bell Telephone Laboratories in 1925. Doctor Jewett is a past president of the AIEE and has been active in its work and that of other societies. He has received the Edison Medal of the AIEE, the Faraday Medal of the Institution of Electrical Engineers of Great Britain, the Washington Award, and the John Fritz Medal, among other honors. During the World War he served as lieutenant-colonel in the Signal Corps and was awarded the Distinguished Service Medal.

O. E. Buckley (M'19, F'29) has been appointed president of the Bell Telephone Laboratories, New York, N. Y. He has been executive vice-president since 1936, and has been associated with the Bell System since 1914. A biographical sketch of Doctor Buckley appeared in the December 1939 issue, page 537.

J. R. North (A'21, M'29) assistant electrical engineer, Commonwealth and Southern Corporation, Jackson, Mich., has been appointed chairman of the AIEE committee on protective devices for the year 1940–41. He has been a member of the committee since 1934 and was vice-chairman 1938–40. He is also a member of the committees on electrical machinery and on the economic status of the engineer, and of co-ordinating committees 3 and 4 of the standards committee. He was born February 20, 1900, at Cambridge, Mass., and received the degree of bachelor of science in electrical engineering at California Institute of Technology in 1923. He was a substation operator for the Southern California Edison Company, Los Angeles, Calif., 1920–23, and in 1922–23 was an assistant instructor in electrical engineering, California Institute of Technology, Pasadena. He then spent a year as student engineer with the Westinghouse Electric and Manufacturing Company, East Pittsburgh and Sharon, Pa. Since 1924 he has been associated with Commonwealth and Southern Corporation and its predecessor company, Commonwealth Power Corporation of Michigan, first as engineer in investigation division, then as assistant investigation engineer (1927), and general technical engineer (1931). He has held his present position since 1939. He has also been active in committee work for the American Standards Association, Edison Electric Institute, and Society of Automotive Engineers.

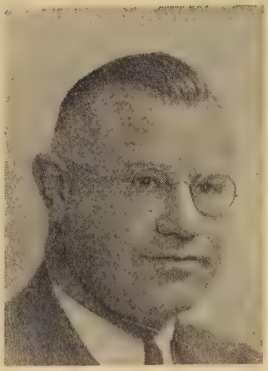
C. M. Gilt (A'21, F'35) inside plant engineer, Consolidated Edison Company of New York, Inc., New York, N. Y., has been appointed chairman of the AIEE committee on electrical machinery for the year 1940–41. He has been a member of the committee since 1937, and was also a member 1926–31. He formerly was a member of the standards committee, and is at present a member of its co-ordinating committee 4. Born in Auburn, N. Y., in 1892, he received the degrees of bachelor of arts, University of Rochester, 1914; bachelor of science, Massachusetts Institute of Technology, 1917; and master of science in electrical engineering, Union College, 1919. He entered the test course of the General Electric Company, Schenectady, N. Y., in 1917, and the following year was transferred to the lighting engineering department, continuing there until 1923 when he went to the Brooklyn (N. Y.) Edison Company. He became inside plant engineer in 1926, outside plant engineer in 1931, and assistant electrical engineer in 1932. When the engineering work of the Consolidated Edison system was centralized in 1937 he became inside plant engineer of the Consolidated Edison Company. He is a member of Phi Beta Kappa.

C. C. Levy (A'33) industry engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., has been appointed chairman of the Institute's committee on electrochemistry and electrometallurgy for 1940–41. He has been a member of the committee since 1934. He was born September 18, 1886, at Lucea, Jamaica, British West Indies, and studied electrical engineering 1909–12 at the School of Practical Science, Toronto University. During 1905–06 he was a switchboard operator for the New York (N. Y.) Edison Company. He was an electrical draftsman for Canadian General Electric Company, Toronto, 1912–13, and since 1913 has been associated with the Westinghouse company. He was first employed as switchboard draftsman, became designing engineer in the switchboard department in 1916, and in 1920 was placed in charge of switchboard drafting. He became automatic switching engineer in 1922. Since 1930 he has been engaged in application engineering, specializing in the electrochemical and chemical industries, and recently has been concerned with industry problems and application practice in inductive heating and melting.

J. J. Orr (A'30) engineer, central staff, United States Rubber Company, New York, N. Y., has been appointed chairman of the AIEE committee on industrial power applications for 1940–41. He has been a member of the committee since 1937 and is also a member of co-ordinating committee 4 of the standards committee. Born April 9, 1902, at Manistique, Mich., he studied engineering at the University of Michigan. He was employed by the Oakland Motor Car Company, Pontiac, Mich., as an electrician in 1919–20 and as a draftsman 1924–26. When the company became the Pontiac division of General Motors Corporation in 1926 he became an assistant electrical engineer, and in 1928 he became electrical engineer. During 1930–31 he was plant engineer for A. J. Brandt, Inc., construction engineering firm in Detroit, Mich. He joined the staff of United States Rubber Company, New York, in 1932, as electrical engineer. In 1933 he was transferred to Providence, R. I., as plant engineer, and in 1936 was made manager of planning and engineering at Providence. Since 1938 he has been with the central engineering staff, which supervises engineering and development in about 20 plants in the United States and Canada.

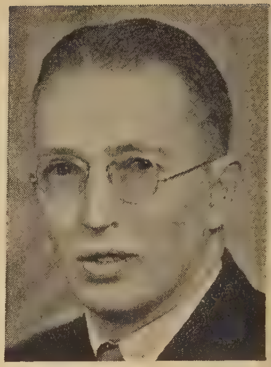
E. B. Fitzgerald (A'26, M'31) electrical engineer, American Car and Foundry Company, Berwick, Pa., has been appointed chairman of the AIEE committee on land transportation (formerly the committee on transportation) for the year 1940–41. He has been a member of the predecessor committee since 1935. He was born at Greenfield, Mass., May 20, 1901, and received the degree of bachelor of science in electrical engineering from Norwich University in 1924. In 1924 he entered the graduate student course of the Westinghouse Electric and Manufacturing Company at East Pittsburgh, Pa., where he was engaged in special work in connection with the electrification of the Norfolk and Western and Virginian railroads; later he was transferred to Bridgeport, Conn., as service engineer. He entered the employ of the J. G. Brill Company, Philadelphia, Pa., in 1926 as assistant electrical engineer in the automatic car division, and in 1930 was made electrical engineer. He has been with the American Car and Foundry Company since 1935. He has been active also in committee work for the American Transit Engineering Association and the National Fire Protection Association.

W. L. Cisler (M'35) assistant chief engineer, electrical engineering department, Public Service Electric and Gas Company, Newark, N. J., has been appointed chairman of the AIEE committee on power generation for 1940–41. He has been a member of the committee since 1935. Born October 8, 1897, at Marietta, Ohio, he received the degree of mechanical engineer from Cornell University in 1922, and since that time has been continuously employed by Public Service Electric and Gas Company. He entered the service of the company as cadet engineer in the training course, and from 1924 to 1926 was test engineer in the Marion and Kearny generating stations. In 1926 he became assistant chief engineer at the Peterson generating station, and in 1927 chief engineer of the Marion station. From 1931 to 1935 he was planning and installation engineer, and in 1935 he became general superintendent of generation. He was made assistant general manager of the electric department in 1936 and assumed his present position in 1938.



J. J. ORR

C. C. LEVY



E. B. FITZGERALD

A. E. Anderson (A'23, M'34) switchgear engineering division, General Electric Company, Philadelphia, Pa., has been appointed chairman of the AIEE committee on automatic stations for the year 1940–41. He has been a member of the committee since 1931. Born May 26, 1897, at Falmouth, Mass., he received the degree of bachelor of science in electrical engineering from Worcester Polytechnic Institute in 1920. His affiliation with General Electric began in 1918, in the testing department at Schenectady, N. Y., and was twice interrupted, by service in the United States Army and the Ordnance Department, and by his final year at college. Since 1920 he has been continuously with the company; from 1920 to 1932 responsible for application and design of automatic switching equipment for use with nonrotating apparatus, and since 1932 concerned with both manual and automatic control switchgear. He is the author of papers and articles on switchgear, and holds 60 patents, mostly relating to switchgear and control apparatus.

J. D. Wright (A'36) assistant manager, industrial department, General Electric Company, Schenectady, N. Y., has been appointed chairman of the Institute's committee on electric welding for the year 1940–41. He was born at Baraboo, Wis., April 11, 1887, and received the degree of bachelor of science from the University of Wisconsin in 1909. Since graduation he has been continuously employed by General Electric. He was first a student engineer in the testing department, then engineer in the industrial control engineering department. He was transferred to the steel mill section of the industrial engineering department in 1915 and placed in charge of the section in 1922. In 1930 he became assistant engineer of the industrial department, and in 1936 assistant manager. He was a member of the Institute's former committees on the iron and steel industry and applications to iron and steel products, and is a member of the committee on industrial power applications (chairman 1938–40).

K. S. Wyatt (A'32, M'39) formerly technical director of the Enfield Cable Works, Ltd., London, has joined the staff of the Habirshaw Cable and Wire Division of the Phelps Dodge Copper Products Corporation of New York, N. Y. Mr. Wyatt attended Mount Allison University, Sackville, N. B., Canada, receiving the degrees of bachelor of arts (1921) and bachelor of science (1922), and later did graduate work at Harvard University and the University of Toronto. He was an assistant research chemist for the Carborundum Company, Niagara Falls, N. Y., in 1922–23. The Detroit Edison Company, Detroit, Mich., employed him in 1928 as research engineer on cable insulation. He continued in that position until 1938 at which time he became affiliated with the Enfield Cable Works. Mr. Wyatt is a member of the American Chemical Society and has been associated with a number of national committees on cables and insulation. He is author and co-author of many papers on cable insulation.

C. M. Sherer (A'39) test engineer, Pennsylvania Water and Power Company, Holtwood, Pa., has been awarded the District 2 prize for initial paper for 1939, jointly with K. J. Granbois, for their paper "An Unusual Case of A-C Electrolysis on Single-Phase Power Cables." A native (1895) of Mannheim, Pa., Mr. Sherer received the degree of bachelor of science from Gettysburg College in 1920, and spent a few months with the Edison Lamp Works of General Electric Company at Newark, N. J., before entering the test department of the Pennsylvania Water and Power Company in 1921.

W. R. Schofield (F'32) formerly chief engineer, Leeds and Northrup Company, Philadelphia, Pa., has been made director of engineering. Born October 20, 1895, at Phila-

W. L. CISLER

J. D. WRIGHT

A. E. ANDERSON

delphia, Pa., he studied at the University of Pennsylvania. He has been with Leeds and Northrup since 1916. First employed as a draftsman, he was engaged in designing electrical instruments from 1919 to 1925, and from 1921 was also engineer. He became assistant chief engineer in 1925, and chief engineer in 1928. He is a member of the Institute's committee on electrochemistry and electrometallurgy, and is also a member of The American Society of Mechanical Engineers.

Lloyd Espenschied (A'18, F'30) research consultant, Bell Telephone Laboratories, New York, N. Y., has been awarded the Medal of Honor of the Institute of Radio Engineers, "for his accomplishments as an engineer, as an inventor, as a pioneer in the development of radio telephony, and for his effective contributions to the progress of international radio co-ordination." A native (1889) of St. Louis, Mo., Mr. Espenschied graduated in industrial electrical engineering from Pratt Institute in 1909. After a year as assistant engineer for the Telefunken Wireless Telegraph Company of America, he joined the engineering staff of the American Telephone and Telegraph Company as development engineer in 1910. He was transferred to Bell Telephone Laboratories in 1934. He received the AIEE national prize for best paper in theory and research in 1935.

K. J. Granbois (A'31) test engineer, Safe Harbor Water and Power Company, Conestoga, Pa., has been awarded District 2 prize for initial paper for 1939 jointly with C. M. Sherer, for their paper "An Unusual Case of A-C Electrolysis on Single-Phase Power Cables". Mr. Granbois, a native (1905) of Rosholt, S. Dak., received the degree of bachelor of science in electrical engineering from the University of Minnesota in 1929, and after a year on transformer testing with the Westinghouse Electric and Manufacturing Company at Sharon, Pa., entered the testing department of the Pennsylvania Water and Power Company, Holtwood. He assumed his present position in 1935.

F. A. Compton, Jr. (A'39) d-c armored motor engineering department, General Electric Company, Erie, Pa., was awarded the District 2 prize for best paper for 1939, for his paper "Application of Class B Insulation to Auxiliary Type D-C Motors in Heavy-Duty Service." Mr. Compton, who received the degrees of bachelor of arts in 1927 and electrical engineer in 1928 from Stanford University, has been associated with General Electric Company at Erie since 1929. He was first employed in the motor division of the transportation engineering department and in 1936 was transferred to his present work on d-c armored motors.

E. F. King (A'37) engineer, radiant heat division, C. M. Hall Lamp Company, Detroit, Mich., was awarded the District 2 prize for graduate student paper for 1939 for his paper "Photoelectric Stress Studies of Small Objects in Motion." A native (1913) of Falmouth, Ky., he received the degree of electrical engineer from the University of Cincinnati in 1936. He was employed as electrician by the Pure Oil Company, Cincinnati, Ohio, 1936–37, and was teaching fellow in electrical engineering at the University of Cincinnati for two years before assuming his present position.

H. C. Robertson (A'40) Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., received the District 2 prize for Branch paper for 1939, for his paper "Electricity in Medicine", written while he was a student at Johns Hopkins University. He received the degree of bachelor of engineering from that institution in 1939, and after a summer's work for the Eastern Shore Public Service Company, Salisbury, Md., entered the student course at Westinghouse in the fall of that year.

R. E. Bailey (A'37) formerly division manager, Utah Power and Light Company, Park City, Utah, has been appointed manager of the southern division of the company. He joined the company in 1914 as power salesman, becoming superintendent of power sales in 1915, assistant to the commercial manager in 1924, and manager of the Park City division in 1926.

W. D. Coolidge (A'10, M'34) director of research laboratory, General Electric Company, Schenectady, N. Y., has been appointed to the recently organized National Inventor's Council, created to encourage civilian inventions as part of the national defense program.

Obituary • • •

Charles Frederick Uebelacker (A'90, M'93) retired vice-chairman, Ford, Bacon and Davis, Inc., New York, N. Y., died September 17, 1940. He was born at Rochester, N. Y., April 8, 1868, and completed the electrical-engineering course at Princeton University in 1890. He entered the employ of the Brush Electric Manufacturing Company, Cleveland, Ohio, as an apprentice and within three years rose to the position of assistant superintendent. In 1893 he became associated with the Consolidated Traction Company, N. J., becoming successively division superintendent, master mechanic, and chief engineer. From 1897 to 1899 he was general manager of works of the Peckham Motor Truck and Wheel Company, Kingston, N. Y. In the latter year he went with the firm of Ford, Bacon and Davis and remained with this organization until his retirement in 1936. For this firm he served first as vice-president and general manager of the Elmira (N. Y.) Water, Light and Railroad Company; in 1901 assumed the duties of chief engineer of Ford, Bacon and Davis in New York, and in 1912 was made a partner in the firm. When the firm was incorporated in 1921 he became chairman of the board of directors, serving as such until 1927. In 1934 he was made vice-chairman until his retirement. During the World War he acted as consulting engineer and chief technical adviser to D. C. Jackling, director of explosives for the War Department. Mr. Uebelacker was a member of The American Society of Mechanical Engineers; Princeton Alumni Association of Northern New Jersey; Princeton Engineering Association; and, prior to his retirement, the Engineers Club, New York, and various other clubs.

William Charles Boyrer (A'09, M'22, F'24) retired electrical engineer of the Consolidated Edison Company of New York, Inc., died September 28, 1940. He was born in New York, N. Y., December 18, 1869; he received the degrees of bachelor of science in 1890 from the College of the City of New York, and mechanical engineer in 1891 and master of mechanical engineering in 1892 from Cornell University. In 1892 he entered the student course of the General Electric Company; from November 1892 to June 1893 was affiliated with Queen and Company, Philadelphia, Pa.; and from 1893 to 1894 with Pepper and Register, Philadelphia. He was associated with the New York Navy Yard from 1894 to 1895; the New York and New Jersey Telephone Company, 1895–1903 (division engineer 1899–1903); assistant to superintendent of construction, American Telephone and Telegraph Company, 1903–08; electrical engineer, Public Service Commission for the First District, State of New York, 1908–24; executive staff, New York Edison Company, 1924. He remained with this company and its successor, the Consolidated Edison Company, until his retirement in 1937. Mr. Boyrer was the author of several books on telephone engineering. He was a member of the National Electric Light Association; Telephone Pioneers of America; Theta Delta Chi; the Steuben Society of America, the Brooklyn Engineers' Club, and the

Mathematical Society of America. He was active in the forming of the AIEE South Carolina Section.

Charles Ambrose Crapo (M'23) equipment and buildings engineer, Mountain States Telephone and Telegraph Company, Denver, Colo., died September 2, 1940. He was born November 4, 1876, at Chicago, Ill., and educated there. He was employed as a switchboard installer by the Chicago Telephone Company in 1890; became instrument installer in 1893, and switchboard maintenance man in 1896. In 1902 he was transferred to the Colorado Telephone Company, Denver, and in 1905 was appointed equipment engineer. When the Colorado Telephone Company and the Rocky Mountain Bell Telephone Company consolidated in 1911 to form the Mountain States Telephone and Telegraph Company, he continued in the same position, and in 1920 became engineer of equipment and buildings. He had completed 50 years of telephone service on June 1, 1940.

William G. Quirk (A'16, M'27) engineer, division of street lighting and exterior electrical distribution, Department of Water Supply, Gas, and Electricity, City of New York, N. Y., died September 10, 1940. He was born in New York, N. Y., February 28, 1879, and studied at Cooper Union. Since 1900 he had been associated with lighting for the City of New York. He was inspector of construction and operation of electric building and street lighting installations, later becoming general inspector in charge of the bureau of lamps and lighting. In 1915 he was made supervising general inspector in charge of the division of street lighting and exterior electrical distribution, and continued to hold that position until his death. He was also a member of the Illuminating Engineering Society.

Savel Bernard Kyne (formerly Kanevsky) (A'37) assistant electrical engineer, Connecticut Light and Power Company, Willimantic, Conn., died August 21, 1940. Born in Russia, July 30, 1885, he received the degree of bachelor of science in electrical engineering from Cooper Union in 1919. He joined the Connecticut Light and Power Company in 1924 as assistant electrical engineer on design of substations and transmission lines, at Norwich, Conn., and was later transferred to Willimantic.

Kenneth John Kiefer (A'36) transit man, Works Progress Administration, Cleveland, Ohio, died March 9, 1940, according to information recently received. He was born at Cleveland March 17, 1911, and received the degree of bachelor of science in electrical engineering from the Case School of Applied Science.

Membership • •

Recommended for Transfer

The board of examiners, at its meeting on October 17, 1940, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the national secretary.

To Grade of Fellow

Evans, R. D., consulting transmission engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
Harrell, F. E., assistant chief engineer, Reliance Electric and Engineering Co., Cleveland, Ohio.
Martindale, Roy, assistant chief electrical engineer and general manager, Bureau of Power and Light, Los Angeles, Calif.
Nye, H. V., engineer in charge, switchgear design, Allis-Chalmers Manufacturing Company, West Allis, Wis.

4 to Grade of Fellow

To Grade of Member

Blankenbuehler, J. H., design engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
Bowman, J. H., associate professor of electrical engineering, Purdue University, West Lafayette, Ind.
Daley, J. L., assistant professor of electrical engineering, Yale University, New Haven, Conn.
Dunn, Charles, associate electrical engineer, The Bonneville Power Administration, Portland, Ore.
Evans, C. W., editor, *Electrical South*, Atlanta, Ga.
Garrett, W. A., district plant engineer, American Telephone and Telegraph Company, Albuquerque, N. Mex.
Hills, H. W., engineer, Jackson and Moreland, Boston, Mass.
Lee, A. W., vice-president in charge of operation, Louisville Gas and Electric Company, Louisville, Ky.
Meyer, E. M., chief electrical engineer, Victor Insulators, Inc., Victor, N. Y.
Paxson, H. R., relay engineer, Philadelphia Electric Company, Philadelphia, Pa.
Ramakrishna, R., superintendent of transmission lines, Government of Mysore, Bangalore, S. India.
Sawford, Frank, mechanical and electrical engineer, Vancouver, B. C., Canada.
Steeves, C. M., electrical engineer, Sao Paulo Tramway Light and Power Co., Sao Paulo, Brazil.
Tole, J. H., sales engineer, Westinghouse Electric and Manufacturing Company, Memphis, Tenn.
Zimmerman, S. W., research engineer, General Electric Company, Pittsfield, Mass.

15 to Grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Names of applicants in the United States and Canada are arranged by geographical Districts. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the national secretary before November 30, 1940, or January 31, 1941, if the applicant resides outside of the United States or Canada.

United States

1. North Eastern

Cady, C. A. (Member), General Radio Company, Cambridge, Mass.
Tener, R. S. (Member), General Electric Company, Lynn, Mass.

2. Middle Eastern

Anderson, A. A., Pennsylvania Power and Light Company, Sunbury, Pa.
Brangan, C. S., Bra Bon Electric Company, Incorporated, Philadelphia, Pa.
Brown, A. G., Chicago Pneumatic Tool Company, Cleveland, Ohio.
Creveling, A. B., Jr., American Car and Foundry Company, Berwick, Pa.
Cullen, E. P., Philadelphia Electric Company, Philadelphia, Pa.
Dyke, L. B., Philadelphia Electric Company, Philadelphia, Pa.
Gargan, T. V., Anaconda Wire and Cable Company, Philadelphia, Pa.
Howe, E. G., General Electric Company, Philadelphia, Pa.
Jungk, H. G. (Member), Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
McKean, A. H. (Member), Allegheny Industrial Electrical Company, Incorporated, Pittsburgh, Pa.
Phair, R. S., E. G. Budd Manufacturing Company, Philadelphia, Pa.
Rupar, A. B., Elkland Electrical Company, Incorporated, Elkland, Pennsylvania.
Schreiber, M. A., Bethlehem Steel Company, Sparrows Point, Md.
Senior, G. A., Philadelphia Electric Company, Philadelphia, Pa.
Steinbright, W. G., Philadelphia Electric Company, Philadelphia, Pa.
Theon, A. B., Reliance Electric and Engineering Company, Cleveland, Ohio.
Tibbs, R. H. (Member), Chesapeake and Potomac Telephone Company, Washington, D. C.
Warren, S. R., Jr. (Member), Moore School of Electrical Engineering, Philadelphia, Pa.
Weeks, L. H., Copper Wire Engineering Association, Washington, D. C.

3. New York City

Cornell, B. S., New York Telephone Company, New York, N. Y.
Ingram, M., Brooklyn Edison Company, Incorporated, Brooklyn, N. Y.
MacDaniels, R. B., New York City Tunnel Authority, New York, N. Y.
McManus, J. J., Consolidated Edison Company of New York, Incorporated, New York, N. Y.
Nelson, J. K., Western Union Telegraph Company, New York, New York.
Overgaard, H., Ebasco Services Incorporated, New York, N. Y.
Reinhardt, E. F., Public Service Electric and Gas Company, Jersey City, N. J.
Walker, R. I., New York City Board of Transportation, IRT Division, New York, N. Y.

4. Southern

Morton, H. C., Westinghouse Electric and Manufacturing Company, Memphis, Tenn.
Welch, W. T., New Orleans Public Service Incorporated, New Orleans, La.

5. Great Lakes

Ambelang, C. E. (Member), Public Service Company of Northern Illinois, Chicago, Ill.
Bowman, R. J., Illinois Testing Laboratories, Incorporated, Chicago, Ill.
Briggs, W. A., Carnegie-Illinois Steel Company, Chicago, Ill.
Gray, P. G., Michigan State College, East Lansing.
Kennedy, J. T. (Member), Cutler-Hammer, Incorporated, Milwaukee, Wis.
Kezer, J., Commonwealth Edison Company, Chicago, Ill.
Lenten, N. W., Cutler-Hammer, Incorporated, Milwaukee, Wis.
Neal, E. C., Ford Motor Company, Dearborn, Mich.
Nicolai, N. A. (Member), Indiana Bell Telephone Company, Indianapolis, Indiana.
Posselt, E. J. (Member), Cutler-Hammer, Incorporated, Milwaukee, Wis.
Raven, G. F., The Commonwealth and Southern Corporation, Jackson, Mich.
Steel, F. K. (Member), Chicago, Burlington and Quincy Railroad Company, Chicago, Ill.

7. South West

Duerkob, M. F., Bussmann Manufacturing Company, St. Louis, Mo.
Greenslade, W. F., Jr., J. W. Beretta Engineers, Incorporated, San Antonio, Texas.
Norvell, R., West Texas Utilities Company, Dalhart, Texas.
Salis, A. E., Agricultural and Mechanical College of Texas, College Station, Texas.
Williams, J. H., Carter Oil Company, Tulsa, Okla.

8. Pacific

Brokaw, G. K., care C. E. Bentley, 216 Pine St., San Francisco, California.
Bruce, W. C., Southern California Telephone Company, Los Angeles, Calif.
Ganssle, K. A., Southern California Telephone Company, Los Angeles, California.
Gould, E. H., Jr., Navy Yard, Mare Island, Calif.
Harsin, A. W., Southern California Telephone Company, Los Angeles, Calif.
Nott, W. M., Sangamo Electric Company, San Francisco, Calif.
Pickering, W. H., California Institute of Technology, Pasadena, Calif.
Poynter, W. F., Pacific Electric Manufacturing Corporation, San Francisco, Calif.
Reibold, C. T., Southern California Telephone Company, Los Angeles, Calif.

9. North West

Burton, F. J., Seattle Transit System, Seattle, Wash.
Green, J. P., Washington Water Power Company, Spokane, Wash.
Hatfield, D. W., Utah Copper Company, Garfield, Utah.
Ryan, J. C., Montana Power Company, Butte, Montana.
Uhlig, R. A., Washington Water Power Company, Spokane, Wash.

10. Canada

Brown, R. J. (Member), University of Toronto, Toronto, Ont.
Cadario, H. P., Hydro Electric Power Commission of Ontario, Toronto, Ont.
Clement, L. D. L., Hydro Electric Power Commission of Ontario, Toronto, Ont.
Phillips, N. E., Hydro Electric Power Commission, Toronto, Ont.
Smith, W. H., English Electric Company of Canada, Limited, St. Catharines, Ont.

Total, United States and Canada, 67

Elsewhere

Chemor, T. A. (Member), Mexico Tramways Company, Mexico, D. F., Mexico.
Fuller, R. G. (Member), British-American Tobacco Company, Limited, Shanghai, China.
Hogle, C. R. (Member), The Panama Canal, Balboa Heights, Canal Zone.
Rodriguez, E., Manila Steamship Company, Manila, P. I.
Wilson, R. S., Manila Electric Company, Manila, P. I.

Total, elsewhere, 5

Of Current Interest

From A E C . .

ITEMS appearing under this heading are from the news service of American Engineering Council.

Army-Navy Defense Orders Mount as Congress Completes Appropriations

Organization of an Atlantic Fleet by the Navy, a $25,000,000 loan to China to be repaid by shipments of tungsten, the extension of embargoes on United States exports of war materials and supplies, and the completion of an appropriation program by Congress allotting over $12,000,000,000 for defense needs marked an eventful month in Washington.

Of the money earmarked for defense, $8,347,400,507 is in direct appropriations, while an additional sum approaching $4,000,000,000 takes the form of contract authorizations to be met from later appropriations. Not included is full cost of the two-ocean navy, which will cost an estimated $5,000,000,000 over a five-year period, and for which direct appropriations of only $148,000,000 so far have been made.

Major items to be secured by this expenditure include:

Complete equipment for an army totaling 1,400,000 men, and arms for an additional 600,000.

Air forces of 25,000 planes for the Army and 10,000 for the Navy.

Construction and rehabilitation of a large number of Army and Navy bases.

Financing of munitions plants.

Two new units have been created by executive order to handle specific problems connected with the defense drive. The Defense Communications Board will coordinate plans for the war-time use of cable, wire, and radio facilities with due regard to the needs of the armed services, the Government, and the general public. It is composed of the chairman of the Federal Communications Commission, the director of naval communications, the chief signal officer of the Army, an assistant secretary of state, and an assistant secretary of the treasury. The Health and Medical Advisory Committee will advise on the problem of securing adequate medical staffs for the expanded Army and Navy without unnecessary dislocation of present medical facilities in both rural and urban districts.

The United States has now adopted the policy of placing an embargo upon the exportation of scrap steel, an important war material, to all countries except Great Britain and the countries of the Western Hemisphere. Also subject to strict export licensing are aircraft, airplane engines, aviation gasoline, and tetraethyl lead, as well as equipment for their production and technical information useful in the design, construction, and operation of such equipment.

An announcement of general policy by the National Defense Advisory Commission early in September calling for full compliance with labor laws by Government contractors has been followed up by an informal opinion on the part of Attorney-General Robert H. Jackson to the effect that firms which have been found to be violators of the National Labor Relations Act may be refused defense contracts until the finding is reversed by a court.

MANY CONTRACTS AWARDED

Actual placing of defense orders is going on at so rapid a rate that attempted summaries are out of date before they can be printed. The Navy signed contracts for 200 new vessels on the day the appropriation act making them legal became law, and the Army has awarded over $1,000,000,000 in orders in one eight-day period. A recent unofficial survey made by Moody's Investors Service estimates unfilled orders in the United States to supply domestic and foreign demands at over $8,000,000,000, with actual awards by the American Army and Navy in the period from July 1 to September 25, 1940, as follows: ships, $4,471,744,000; construction, $474,177,000; automobiles, $316,627,000; aircraft, $737,428,000; arms, $309,230,000; chemicals, $119,217,000; railroad equipment, $97,267,000. Since this date many additional contracts have been awarded, and construction contracts for 50 munitions plants to cost over $500,000,000 were pending at press time.

Machine-tool builders have orders on hand totaling $750,000,000 from both domestic and foreign sources, according to a survey by the magazine *American Machinist*, and is scheduling deliveries well into 1941. The present annual capacity of the industry is set at $450,000,000, which will be increased to $500,000,000 by the end of 1940.

Efforts are being made to decentralize defense orders, and particularly to stimulate the construction of new plants in nonindustrial areas remote from frontiers to minimize the interruption to production from possible bombing raids. The War Department is reported to be suggesting the construction of air-raid shelters for the use of workers engaged in the production of munitions.

HOUSING FACILITIES

An allotment of $45,762,500 has been made to the Public Buildings Administration, a division of the Federal Works Agency, for the construction of housing projects to serve the Army. This sum is expected to provide accommodations for at least 13,000 families, to be built under cost-plus-a-limited-fee contracts. The first 70 projects to be designated were located in 28 states, Hawaii, and Puerto Rico. In 19 instances the necessary land already was owned by the Army; in the others it must be acquired. Funds for this work were allotted to the Army by Congress subject to a maximum cost limitation of $3,500 per dwelling unit, including land, utilities, and services, and the program will be supervised by the PBA in conformity with an official request by the Secretary of War.

Employment of Engineers in Defense Program

Engineers who wish to offer their services to the Federal Government in the defense program have three main avenues of approach: (1) direct employment; (2) engagement on a consulting basis; and (3) as an employee or consultant of a contractor having a Government contract. A brief outline of how employment in these three categories may be accomplished follows.

DIRECT EMPLOYMENT

With relatively few exceptions, employment in Government departments, bureaus, independent agencies, and the like is under Civil Service rules and regulations. Competitive examinations produce so-called eligible lists, from which names are certified to those Government agencies making requests. Personnel is being added to several agencies directly concerned with the defense program, such as War, Navy, and the Defense Commission, but most appointments are being made from Civil Service eligible lists already in existence. Many jobs are being handled by calling reserve officers of the Army and Navy to active duty. Thus the chance of obtaining direct employment is somewhat remote for those not having Civil Service status or not being in the organized reserves.

CONSULTING BASIS

The engagement of engineers on a consulting basis is handled by each Government agency in accordance with rules and regulations of long standing, although in a few cases recent simplifications to expedite procedure have been made. In general, compensation is on a per diem basis, and only in exceptional cases does the rate exceed $25 per day. Many Government agencies at times use consultants, but at the present time and in carrying out the defense program, the Army, Navy, and the Panama Canal are the principal agencies taking on engineering consultants.

Applications for consulting work in the Army are being handled by the recently appointed Construction Advisory Board consisting of Francis Blossom, Forrest S. Harvey and J. F. C. Dresser. Communications to this board should be addressed to 1125 Munitions Building, Washington, D. C. Requests for consideration should be accompanied by a full statement of experience, especially records of jobs accomplished. Applications from engineering firms as well as from individuals may be sent to this board. A similar list for the Navy is being compiled by Lieutenant A. D. Hunter, Bureau of Yards and Docks, Navy Department, Washington, D. C.

As is generally known, the national engineering societies have sent questionnaires to their members to compile information respecting those individuals or firms who are available for consulting work. The information gleaned from these questionnaires is now filed with the more important Government agencies. Members of engineering societies should address their communications to the secretaries of their respective societies.

CONTRACTORS' STAFFS

Contractors on defense work of course will engage their own employees and consultants. The policy adopted by the Government is to award contracts, whether for the consulting services of engineers, or for construction, to those qualified to handle the work who reside in the region where it is to be done. In a few cases, the construction contract also includes the design, but this is exceptional. However, engineering firms that are also contractors might well make their qualifications known to the Construction Advisory Board.

It should be understood that the National Defense Advisory Commission itself awards no contracts, but merely serves as a co-ordinator to assist the regular Federal agencies in carrying out their individual programs.

Other Societies ●

Industrial Research Institute to Conduct Defense Inventory

Problems of industrial-research management and of the design of research laboratories were discussed by some 50 active executives in this field at the meeting of the Industrial Research Institute held September 27–28, in Swampscott, Mass. The meeting included a session of the organization's executive committee, technical sessions featuring addresses on pertinent subjects and round-table discussions, and inspection trips to nearby industries.

An affiliate of the National Research Council, the Industrial Research Institute was organized several years ago for the purpose of improving efficiency and effectiveness in the management of industrial research, through co-operation of its members. The membership is composed of industrial concerns maintaining research laboratories as a part of their organizations. Top executives in charge of research of the member companies represent them in the activities of the group.

At the business session, which closed the two-day meeting, the members voted to cooperate in a survey of special facilities and key personnel of their respective organizations in the interest of the national-defense program. It was announced also that the office of the secretary was being moved from New York to 8 South Michigan Avenue, Chicago, Ill., to be near that of the chairman, H. Earl Hoover, vice-president, The Hoover Company. Maurice Holland (A'23, M'30) director, division of engineering and industrial research, National Research Council, will continue to represent the organization at its New York office.

New "Who's Who in Engineering"

Engineers throughout the country now are being canvassed for biographical material preparatory to publication of a new (fifth) edition of "Who's Who in Engineering." Like the preceding edition (1937) the new volume is being produced under the editorship of Doctor W. S. Downs and will be published by the Lewis Historical Publishing Company, New York, N. Y.

Qualifications for inclusion in the volume have been established by a committee composed of the following: A. A. Potter, *chairman*, dean, schools of engineering, Purdue University; L. B. Lent, *vice-chairman*, executive secretary, American Engineering Council; F. L. Bishop, secretary, Society for Promotion of Engineering Education; C. E. Davies, secretary, American Society of Mechanical Engineers; H. H. Henline, national secretary, American Institute of Electrical Engineers; T. Keith Legare, secretary, National Council State Boards of Engineering Examiners; A. B. Parsons, secretary, American Institute of Mining and Metallurgical Engineers; G. T. Seabury, secretary, American Society of Civil Engineers; S. L. Tyler, secretary, American Institute of Chemical Engineers; J. A. C. Warner, secretary and general manager, Society of Automotive Engineers.

New ASME Officers. Election of the following officers has been announced by The American Society of Mechanical Engineers to serve the organization during 1941:

President: William A. Hanley, director, Eli Lilly and Company, Indianapolis, Ind.

Vice-Presidents: Samuel B. Earle, research engineer and dean of engineering, Clemson Agricultural and Mechanical College, Clemson, S. C.; Frank H. Prouty, a partner in Prouty Brothers Engineering Company and Industrial Appraisal Company, Denver, Colo.; and Edwin B. Ricketts, mechanical engineer, Consolidated Edison Company of New York, Inc., New York, N. Y.

Managers: Huber O. Croft, professor of mechanical engineering and head of the department, University of Iowa, Iowa City; Paul B. Eaton, consulting engineer, and professor and head of mechanical-engineering department, Lafayette College, Easton, Pa.; and George E. Hulse (M'22) chief engineer, The Safety Car Heating and Lighting Company, New Haven, Conn.

Future Meetings of Other Societies

Acoustical Society of America. Fall meeting, November 14–15, 1940, Chicago, Ill.

American Association for the Advancement of Science. December 27, 1940–January 2, 1941, Philadelphia, Pa.

American Institute of Chemical Engineers. 33d annual meeting, December 2–4, 1940, New Orleans, La.

American Institute of Mining and Metallurgical Engineers. Annual meeting, February 17–20, 1941, New York, N. Y.

American Physical Society. 238th meeting, December 1940, Pasadena, Calif.

239th meeting (annual), December 26–28, 1940, Philadelphia, Pa.

American Society of Civil Engineers. Annual meeting, January 15–18, 1941, New York, N. Y.

American Society of Heating and Ventilating Engineers. 47th annual meeting, January 27–29, 1941, Kansas City, Mo.

American Society of Mechanical Engineers. Annual meeting, December 2–6, 1940, New York, N. Y.

American Society of Refrigerating Engineers. 36th annual meeting, December 2–6, 1940, New York, N. Y.

National Exposition of Power and Mechanical Engineering, 14th. December 2–7, 1940, New York, N. Y.

National Research Council. Highway Research Board, 20th annual meeting, December 4–6, 1940, Washington, D. C.

Society of Naval Architects and Marine Engineers. Annual meeting, November 14–15, 1940, New York, N. Y.

ASME Annual Meeting. The 61st annual meeting of The American Society of Mechanical Engineers will be held in New York, N. Y., December 2–6, 1940, with meeting headquarters at the Hotel Astor instead of at the Engineering Societies Building as in previous recent years. More than 100 technical papers on such specialized subjects as aeronautics, applied mechanics, fuels, hydraulics, metals engineering, machine-shop practice, management, materials handling, petroleum, steam power, railroads, textiles, heat transfer, and process industries will be presented by leading experts in these fields. To accommodate all these papers, 44 sessions are being scheduled, including 6 for Monday evening, December 2.

Chemical Exposition and Conference. An industrial chemical conference will be held in connection with the National Chemical Exposition, at Chicago, Ill., December 11–15, 1940. New developments in chemistry and chemical engineering will be discussed in papers to be presented on December 12 to 14. The conference and exposition are sponsored by the Chicago Section of the American Chemical Society.

1941 Mechanical Catalog. The 30th annual ASME Mechanical Catalog and Directory, 1941 edition, has just come off the presses and is now being distributed to members of The American Society of Mechanical Engineers as part of their membership privileges. Nonmembers of that society may obtain copies from ASME headquarters, 29 West 39th St., New York, N. Y., for $3.00 each.

Library ● ● ● ●

OPERATED jointly by the AIEE and the other founder societies, the Engineering Societies Library, 29 West 39th Street, New York, N. Y., offers a wide variety of services to members all over the world. Information about these services may be obtained on inquiry to the director.

Periodical Exchange Affected by War

In spite of the war, the Engineering Societies Library is experiencing no difficulty in its receipt of technical periodicals from Great Britain. However, only a few engineering magazines reach the Library now from continental Europe. The 350 or more periodicals from England and other parts of the British Empire are coming through with unusual regularity except in one or two instances since the beginning of the war when the ship carrying a batch of them was sunk by a torpedo or a mine. However, correspondence with the publishers soon brought replacements for all lost copies.

The Allied blockade of Germany failed to stop the flow of German magazines to the Library through Italy. But, with the entrance of the latter country into the war, the Library failed to receive German and Italian publications for several months. Now, some of the German periodicals are being received again through Siberia and Japan, as indicated by the postmarks on the wrappers. *Genie Civil* and other French periodicals ceased arriving at the Library a few weeks after the surrender of France.

To avoid the loss of valuable publications being sent to and received from the British Isles and continental Europe through exchange agreements between engineer-institutions there and the Engineering Societies Library and its co-operating organizations, namely, American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers, and the AIEE, arrangements have been completed to store them in the country of origin until the end of hostilities. Similar arrangements during the World War proved so satisfactory that only one or two sets of foreign periodicals failed to be completed with the resumption of commerce between belligerents.

Industry • • • •

Defense Inventions to Be Judged by National Inventors Council

Civilian inventions relating to national defense are to be evaluated by a technical staff set up by the National Inventors Council, according to recent report. One division of the staff will be concerned with electrical inventions; other divisions with mechanical and chemical inventions.

The Council expects to establish offices in Washington, D. C., where it will serve as a clearing house for civilian suggestions for improving defense and also as a liaison body to relay assignments from defense officials to the inventors best equipped to solve the problems presented. W. D. Coolidge (A'10, M'34) director of research laboratories, General Electric Company, is the member of the Council especially concerned with electrical problems.

New Laboratory for Best Foods

A new $150,000 research and development laboratory has been built and placed in operation by The Best Foods, Inc., at its Bayonne, N. J. plant. The new building is devoted entirely to laboratories and pilot-plant equipment layouts and includes in addition to the general-control-laboratory space a variety of special-purpose facilities housed largely in individual rooms and laboratories. Among the latter are an experimental bakery, four constant-temperature rooms with temperature-regulating and recording equipment, a special bacteriological laboratory, an optical-instruments room, an organic-research laboratory, and a product-development laboratory. About one-fifth of the laboratory space is available for pilot-plant equipment. In a special photographic dark room is housed a Hilger quartz spectrophotometer, which is said to be one of few in the United States. One of the uses of this instrument is to assist in the check and control of vitamin-*A* content of the company's vegetable margarine product.

Included among the large variety of services are steam, compressed air, a four-wire electrical system, and a special intralaboratory telephone system. Lighting is of the indirect type. As a special safety feature, balconies are provided on both of the two floors above ground, providing an egress from every laboratory in the building.

Expansion Program Announced by General Electric Company

A $50,000,000 expansion program recently was announced by Charles E. Wilson, president of the General Electric Company, "for all kinds of plants, equipment, offices, and warehouses." The expansion will affect mainly the company's seven largest factories at Schenectady, N. Y., Erie, Pa., Lynn, Mass., Pittsfield, Mass., Bridgeport, Conn., Philadelphia, Pa., and Fort Wayne, Ind. A substantial part of the expansion program is for the production of national-defense materials.

While the expansion has not been definitely allotted among the various plants, Mr. Wilson said that the largest single item would be some $8,000,000 for the Erie plant where turbines will be made for the United States Navy. The Schenectady expansion will include facilities for manufacturing radio transmitters and receivers for the Army and Navy Signal Corps. The program is expected to increase the company's employment rolls from its present all-time high of 90,000 to 95,000 or 100,000 during the next 15 months.

Electrical Exposition Postponed

Almost coincidentally with the announcement that an electrical-engineering exposition would be held in Philadelphia, Pa., January 27–31, 1941, world conditions became more unsettled, resulting in apprehension which was reflected in slowing the progress of the exposition. "Because of this development," the exposition management has announced, "it appeared that the size and scope of this exposition would not meet the expectations of its committee and management. Being unwilling to project anything less important and consequently less beneficial to the profession and industry, they both believe it would be inopportune to carry through with the present plans in the limited time remaining. It has therefore been decided to postpone the exposition to another year."

"Bell Laboratories Record" Marks 15th Anniversary

The *Bell Laboratories Record*, in its September 1940 issue, commemorates 15 years of existence, the first issue having appeared in September 1925, eight months after the formation of the Laboratories. Its object has been and is to chronicle the activities of the Laboratories for its own staff and for engineers and scientists in the same or related fields.

Initially distributed to the staff of the Laboratories and that of the department of development and research of the American Telephone and Telegraph Company (now a part of Bell Laboratories), the magazine now has a circulation of more than 11,000, including about 700 paid subscribers, and is distributed to administrative and technical personnel of the Bell System, libraries, educational institutions, and technical writers. P. B. Findley (A'27, M'34) is editor, and G. F. Fowler (A'29) circulation manager.

C. G. Suits Assigned New Duties. Known to AIEE members through authorship of several Institute papers, Doctor C. Guy Suits has been appointed assistant to the director of the General Electric Company's research laboratory at Schenectady, N. Y. The post is a new one and will permit Doctor Suits to continue his research while assuming some administrative duties. A graduate of the University of Wisconsin (1927) where he majored in physics and mathematics, Doctor Suits later studied at the Institute of Technology at Zurich, Switzerland, where he obtained the degree of doctor of science in 1929. He has been associated with the General Electric research laboratory since 1930. In 1937 he was chosen by Eta Kappa Nu, honorary electrical-engineering fraternity, to receive its award as the outstanding young electrical engineer of that year. He has been granted 52 patents.

"Time Capsule" Sealed. Buried in a 50-foot well in front of the Westinghouse exhibit building at the New York World's Fair, the "time capsule", an 800-pound seven-foot "cupaloy" metal cylinder containing records of 20th-century life for the information of scientists in the year 6939, has been on display for two years. On September 23, 1940, the capsule was sealed by a compound of pitch and other chemicals, 500 pounds of which was poured down the shaft of the well. Among the records in the capsule is a copy of the 50th Anniversary (May 1934) issue of ELECTRICAL ENGINEERING (see *EE, Oct. '38, p. 430*).

Television in Army Maneuvers. A mobile television unit was used to send scenes of troop movements to the headquarters of the "defending army" in the recent United States Army maneuvers in upper New York State. The campus of St. Lawrence University, Canton, N. Y., was the base of operations for what is said to be the first experiment in the use of television for military purposes. Television pick-up equipment was sent to the scene of military operations on a truck, followed by an Army truck carrying a motor-generator unit. The mobile unit, powered with a 25-watt relay transmitter, sent images to a relay receiver on the chapel tower of the University, where the images were checked and sent via coaxial cable to the control room in the physics building, where a 50-watt transmitter was installed. There the images were scanned on a monitor and retransmitted to television receivers at army headquarters in Canton, Heveulton, and De Kalb Junction, N. Y. In addition to transmitting military maneuvers, the equipment was used to transmit programs for the entertainment of the officers.

Westinghouse Doubles Radio-Plant Space. Three new buildings are being constructed by the Westinghouse Electric and Manufacturing Company for its radio division in Baltimore, Md. The first, a temporary timber structure providing 34,000 square feet of manufacturing space has just been completed. Two additional two-story brick-and-steel buildings, which will add approximately 35,000 square feet of manufacturing, laboratory, and office space, are scheduled for completion by November 15.

Education • • •

Committee to Advise on Defense Training

To assist in the task of utilizing the facilities of engineering schools and colleges in the emergency training of workers for defense industries, John W. Studebaker, United States commissioner of education, has appointed a special advisory committee composed as follows: chairman, Andrey A. Potter, dean of engineering, Purdue University; R. E. Doherty (A'16, F'39) president, Carnegie Institute of Technology; Gibb Gilchrist, dean of engineering, Texas Agricultural and Mechanical College; H. P. Hammond, dean of engineering, Pennsylvania State College; W. O. Hotchkiss, president, Rensselaer Polytechnic Institute; R. S. McBride, consulting engineer; Thorndike Saville, dean of engineering, New York University; C. C. Williams, president, Lehigh University; B. M. Woods, chairman, department of mechanical engineering, University of California; F. L. Bishop, secretary, Society for the Promotion of Engineering Education; Allen W. Horton, Jr., United States Office of Education (secretary).

It will be the task of this committee to aid in devising ways and means of best utilizing the teaching staffs and plants of technical schools in presenting special courses, not necessarily for students of collegiate grade, designed to furnish special skills needed in carrying out the defense program. Funds for this purpose have already been appropriated.

Educators See New Electronic and Lighting Devices

In an all-day conference held October 18 at the lamp division, Westinghouse Electric and Manufacturing Company, Bloomfield, N. J., more than 100 educators from eastern engineering schools were shown some of the latest developments in electronic and illuminating equipment achieved by research workers and engineers of that company. The program included talks by A. E. Snyder, Doctor Charles M. Slack, I. E. Mouromtseff (A'25), Doctor Harvey C. Rentschler, Doctor John W. Marden, and Samuel G. Hibben (A'34), all of the Westinghouse company. D. W. Atwater (A'34) presided. Tours of the lamp manufacturing department, the special-products manufacturing department, and the engineering and research laboratories, and an evening session on bactericidal ultraviolet applications completed the conference.

Among the devices and developments described and demonstrated to the visitors were the Klystron, a new electronic tube for generating ultrahigh-frequency radio waves (tube demonstrated generates 40-centimeter waves and has an output of 150 watts); an ultrahigh-speed X-ray tube capable of making X-ray pictures in one-millionth of a second; new discoveries in bactericidal ultraviolet applications including the instantaneous killing of micro-organisms by intense momentary applications of ultraviolet radiation; and some of the latest developments and devices in fluorescent lighting.

Industrial Scholarships at Cornell. The Cornell University College of Engineering has authorized the use of part of the John McMullen Scholarship Fund to create John McMullen Industrial Scholarships for apprentices in industry selected by the officers of the companies for which they work as men whose value would be increased by an engineering education. Four scholarships of $400 each will be awarded each year. Recipients must be high-school graduates qualified to meet the entrance requirements of the college, must have worked in industry, preferably in a training course, and must be recommended by their employers. It is expected that they will return to the organizations by which they previously were employed. Recipients of the first four scholarships, and nominating companies, are:

S. G. Bohle, Schenectady, N. Y.—General Electric Company; T. J. Hildabrand, Altoona, Pa.—Pennsylvania Railroad; William Evans, Syracuse, N. Y.—Onondaga Pottery Company; William McGaghie, Chicago, Ill.—R. R. Donnelly and Sons.

Letters to the Editor • • •

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers; publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Two-Phase Co-ordinates of a Three-Phase Circuit

To the Editor:

The 1939 AIEE TRANSACTIONS just reached the writer's desk a few days ago. It took almost exactly 100 days in its transit to Changting, its postmark at New York being January 29. The writer wants to thank the Institute officers for its delivery, as periodicals of this sort are a tremendous solace to Chinese educational institutions in their present struggle for existence.

On looking over the pages the attention of the writer fell on the very interesting paper of Kimbark on "Two-Phase Co-ordinates of a Three-Phase Circuit".[2] Three main points have been brought up by the different discussions, namely (1) the title, two-phase, (2) the coefficients of the transformation matrix, and (3) the possibility of avoiding mutual coupling between different axes. The writer would like to discuss these points in that order.

For a suitable title, the writer suggests the impersonal name "cylindrical co-ordinates". Early in 1929 the writer investigated the feasibility of representing three-phase circuits by three-dimensional vectors.[2] A very simple and useful vector, called the isoclinic unit vector and defined as

$$\boldsymbol{u}=(1/\sqrt{3})(\boldsymbol{i}+\boldsymbol{j}+\boldsymbol{k})$$

was then brought to light.[3] A geometrical relation deducible from the method of representation is that the locus of the end of the vector denoting a general unbalanced three-phase quantity (voltage or current) without harmonics is an ellipse. On eliminating the component in the $\boldsymbol{u}$ direction—that is, the zero-sequence component, the ellipse lies on a plane—called the fundamental plane—normal to $\boldsymbol{u}$. The major and the minor axes of this ellipse are respectively equal to the sum and the difference of suitably defined positive- and negative-sequence components. Further, when harmonics exist, the locus lies on a right cylinder having $\boldsymbol{u}$ as its axis, the cross section of the cylinder being determined by the positive- and the negative-sequence components, together with the harmonics not multiples of the third. It is thus seen that the co-ordinates discussed by Kimbark bear a close relationship with the method of representation just given. An appropriate impersonal name is perhaps "cylindrical co-ordinates" or "elliptic co-ordinates", preferably the former.

Coming to the second point, the writer recalls that while attempting to find the properties of the ellipse, he transformed the co-ordinate axes from $\boldsymbol{i}$, $\boldsymbol{j}$, $\boldsymbol{k}$ to an orthogonal right-handed system, $\boldsymbol{u}$, $\boldsymbol{v}$, $\boldsymbol{w}$, having direction cosines as follows:[1]

$$\begin{array}{cccc} & \boldsymbol{i} & \boldsymbol{j} & \boldsymbol{k} \\ \boldsymbol{u} & \dfrac{1}{\sqrt{3}} & \dfrac{1}{\sqrt{3}} & \dfrac{1}{\sqrt{3}} \\ \boldsymbol{v} & \dfrac{\sqrt{2}}{\sqrt{3}} & -\dfrac{1}{\sqrt{6}} & -\dfrac{1}{\sqrt{6}} \\ \boldsymbol{w} & 0 & \dfrac{1}{\sqrt{2}} & -\dfrac{1}{\sqrt{2}} \end{array}$$

These nine coefficients may be written as a matrix or a dyadic or a tensor, according to one's taste. They will be recognized to be those listed in the discussion by Boyajian[1] of Kimbark's paper, multiplied by different factors for each row. Stated in another way, the matrices listed by Boyajian give the direction *numbers* while the matrix given previously contains the direction *cosines*. In terms of the method of representation proposed by the writer, the co-ordinate axes discussed by Kimbark are obtained from the phase axes $\boldsymbol{i}$, $\boldsymbol{j}$, $\boldsymbol{k}$ by a simple rotation, changing $\boldsymbol{i}$ to $\boldsymbol{u}$, $\boldsymbol{j}$ to $\boldsymbol{v}$, and $\boldsymbol{k}$ to $\boldsymbol{w}$.

As to the difficulty in remembering these coefficients, the writer offers two ways out: one geometrical and the other algebraic, both in conformity with a unified theory of three-phase-circuit analysis, namely that based on space vectors and dyadics.[4] In the 1929 paper, the writer picked up these coefficients, not by a hit-or-miss process, but through their geometrical simplicity. As mentioned before, a positive- and a negative-sequence system will combine to form an ellipse on the fundamental plane. This plane being normal to the isoclinic direction, the latter direction, having direction cosines all equal to $1/\sqrt{3}$, is taken as one of the references. On the fundamental plane there are three outstanding lines, namely its intersections with the co-ordinate planes $\boldsymbol{jk}$, $\boldsymbol{ki}$, and $\boldsymbol{ij}$. The line of intersection $(\boldsymbol{j}-\boldsymbol{k})$ between the $\boldsymbol{jk}$ plane and the fundamental plane has direction cosines 0, $1/\sqrt{2}$, $-1/\sqrt{2}$, which may then be taken as the $\boldsymbol{w}$ direction. Finally, the $\boldsymbol{v}$ direction is chosen perpendicular to both $\boldsymbol{u}$ and $\boldsymbol{w}$ forming with $\boldsymbol{w},\boldsymbol{u}$ a right-handed orthogonal system. In vector language, $\boldsymbol{v}$ is obtained as the vector product of $\boldsymbol{w}$ by $\boldsymbol{u}$, that is,

$$\boldsymbol{v}=\boldsymbol{w}\times\boldsymbol{u}$$

Hence the direction cosines as given.

The algebraic method is to obtain the transformations through the use of the unit vectors $\boldsymbol{u}$, $\boldsymbol{f}$, $\boldsymbol{b}$, denoting symmetrical co-ordinates. These have been defined by the writer as:

$$\boldsymbol{u}=\frac{\boldsymbol{i}+\boldsymbol{j}+\boldsymbol{k}}{\sqrt{3}},\ f=\frac{\boldsymbol{i}+a^2\boldsymbol{j}+a\boldsymbol{k}}{\sqrt{3}},\ b=\frac{\boldsymbol{i}+a\boldsymbol{j}+a^2\boldsymbol{k}}{\sqrt{3}}$$

wherein a and a^2 are the two complex cube roots of unity as usual. The appearance of $\sqrt{3}$ in the denominators insure the vectors to be of unit length. To change to "cylindrical co-ordinates", $\boldsymbol{u}$ is defined as before and $\boldsymbol{v}$ and $\boldsymbol{w}$ are defined as the real part and the imaginary part of $\boldsymbol{f}$ or $\boldsymbol{b}$, since they are conjugate, through the simple relations:

$$\boldsymbol{v}=(\boldsymbol{f}+\boldsymbol{b})/\sqrt{2}$$

and

$$\boldsymbol{w}=j(\boldsymbol{f}-\boldsymbol{b})/\sqrt{2}$$

The divisor $\sqrt{2}$ is again introduced to make these vectors unit in length while the j is to make $\boldsymbol{w}$ real. It is of interest to compare these definitions with those given by the writer in deriving the axes for "two-reaction theory".[4] Thus corresponding to the stationary symmetrical co-ordinates, $\boldsymbol{u}$, $\boldsymbol{f}$, $\boldsymbol{b}$, we have the rotating symmetrical co-ordinates $\boldsymbol{u}$, $\boldsymbol{s}$, $\boldsymbol{n}$ defined as: $\boldsymbol{u}$ (same as before), $\boldsymbol{s}=\epsilon^{j\omega t}\boldsymbol{f}$, and $\boldsymbol{n}=\epsilon^{-j\omega t}\boldsymbol{b}$, $\boldsymbol{s}$ being thus a unit vector rotating at synchronous speed and $\boldsymbol{n}$ one rotating at negative synchronous speed. Knowing these complex vectors $\boldsymbol{s}$ and $\boldsymbol{n}$, the $\boldsymbol{d}$, $\boldsymbol{q}$ co-ordinates are simple the real and the imaginary parts of $\boldsymbol{s}$ or $\boldsymbol{n}$. Thus we define: $\boldsymbol{u}$ (same as always)

$$\boldsymbol{d}=(\boldsymbol{s}+\boldsymbol{n})/\sqrt{2}$$

and

$$\boldsymbol{q}=j(\boldsymbol{s}-\boldsymbol{n})/\sqrt{2}$$

These show in a striking way the close relationship between $\boldsymbol{u}$, $\boldsymbol{f}$, $\boldsymbol{b}$, and $\boldsymbol{u}$, $\boldsymbol{v}$, $\boldsymbol{w}$ on the one hand and $\boldsymbol{u}$,$\boldsymbol{s}$, $\boldsymbol{n}$ and $\boldsymbol{u}$,$\boldsymbol{d}$, $\boldsymbol{q}$ on the other. It may also be pointed out that from $\boldsymbol{i}$, $\boldsymbol{j}$, $\boldsymbol{k}$ (the phase axes), $\boldsymbol{u}$, $\boldsymbol{f}$, $\boldsymbol{b}$ and $\boldsymbol{u}$, $\boldsymbol{s}$, $\boldsymbol{n}$ are obtained by unitary transformations while $\boldsymbol{u}$, $\boldsymbol{v}$, $\boldsymbol{w}$ and $\boldsymbol{u}$, $\boldsymbol{d}$, $\boldsymbol{q}$ are obtained by orthogonal transformations. All four have $\boldsymbol{u}$ as a common axis.

Regarding the possibility of avoiding mutual coupling by properly choosing the axes, it is feared that complete elimination is in general impracticable if not impossible. This seems to be the verdict of the theory based either on dyadics or on matrices. In case of partial elimination, there is usually more than one possibility; for example, in addition to the four systems, the following orthogonal transformation will also eliminate coupling partly, in case the network is symmetrical with respect to one phase:

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1/\sqrt{2} & -1/\sqrt{2} \\ 0 & 1/\sqrt{2} & 1/\sqrt{2} \end{bmatrix}$$

As for the general bilateral static network typified by a self-transposed impedance dyadic, it is possible to transform it so that there is no coupling between any axes. The transformation, unlike those for partial elimination, is unique. To determine the transformation, Hamilton-Cayley identity and the three scalar invariants of a dyadic have to be used.[4] In fact, a self-transposed dyadic is known as a "right tensor" characterized by an ellipsoid with three principal axes. When referred to these axes, no coupling exists. From the viewpoint of circuit analysis the difficulty seems to be that each part of the network has its own ellipsoid with different sets of principal axes. It would be very helpful if some one could work out a scheme by which different axes might be used in the same problem at the same time.

In concluding, the writer would like to summarize the advantages of using the transformation matrix for cylindrical co-ordinates as given in this communication as follows:

(1). The values of the coefficients are unique, being the direction cosines (not direction numbers) of axes easily remembered from the geometrical or the algebraic exposition already given.

(2). The transformation is a rotation of space; that is, the transformation using direction cosines may be so interpreted. Hence its inverse (or reciprocal) is equal to its transpose.[4] The determinant of the matrix is 1.

(3). The same transformation is used for either current or voltage and yet the expression of power remains both invariant in form and in magnitude. No extra numerical factor occurs.

(4). A simple and unified correlation exists among the four most useful systems known to the profession thus far.

(5). The zero-sequence impedance, that is, Z_{oo} or Z_{uu}, has the same value in all four transformations, $\boldsymbol{u}$, $\boldsymbol{f}$, $\boldsymbol{b}$; $\boldsymbol{u}$, $\boldsymbol{s}$, $\boldsymbol{n}$; $\boldsymbol{u}$, $\boldsymbol{v}$, $\boldsymbol{w}$; and $\boldsymbol{u}$, $\boldsymbol{d}$, $\boldsymbol{q}$.

In mentioning these advantages, the writer is aware of the fact that the magnitudes of the quantities in the $\boldsymbol{u}$, $\boldsymbol{v}$, $\boldsymbol{w}$ directions are not equal to the zero-, the sum and the difference of the positive- and the negative-sequence components as defined by Fortescue. This deserves further comment. It is much like the rationalization of electrical units. In other words, we have here to decide whether we should like to have units in the different axes of the same length, hence the numerics to have extra factors, *or* the numerics to be free from surds and the units to be different in lengths. It is hoped that the whole theory will be more thoroughly examined in this respect by a larger number of persons to see if we can all agree on definitions that will take in as many of the advantages as possible, still preserving a teachable and unified theory. In time an international committee on standardization, probably the International Electrotechnical Commission, should be asked to decide what the best definitions are. Let us all remember the irrational 4π and profit by its history.

REFERENCES

1. TWO-PHASE CO-ORDINATES IN A THREE-PHASE CIRCUIT. **E. W. Kimbark**, AIEE TRANSACTIONS, volume 58, 1939, pages 894–910.

2. REPRESENTATION OF POLYPHASE SYSTEMS BY MULTI-DIMENSIONAL VECTORS. **A. P-T. Sah**, *Proceedings*, World Engineering Congress, Tokyo, 1929, paper no. 171.

3. DYADIC ALGEBRA APPLIED TO THREE-PHASE CIRCUITS. **A. P-T. Sah**, ELECTRICAL ENGINEERING (AIEE TRANSACTIONS), volume 55, August 1936, pages 876–82.

4. DYADIC CIRCUIT ANALYSIS (a book). **A. P-T. Sah**, International Textbook Company, Scranton, Pa., 1939.

A. PEN-TUNG SAH (A'35, M'36)

(President, National University of Amoy, Changting, China)

"Electromagnetic Problems in Electrical Engineering"

To the Editor:

I am much indebted to Mr. Higgins for his letter on pages 246–7 of the June issue of ELECTRICAL ENGINEERING, in which he points out an error in the solution I gave some years ago for the problem of the magnetic field due to a long straight permeable wire in air. Higgins is quite right in his assertion that the vector potentials inside and outside the wire must reduce to equality at the surface of the wire, that is, the vector potential is continuous at the interface. I was evidently led to my erroneous sentence, quoted from page 276 of my book, by the necessity of maintaining the tangential magnetizing force continuous at the interface, completely overlooking the fact that my statement was inconsistent with the requirement of continuity in the vector potential.

It is to be noted, however, that Higgins has made a serious error in his attempt to provide the corrected solution. His condition (*c*) is virtually a statement that the tangential induction is continuous at the interface, which is obviously quite incorrect for a permeable wire. In reality it is the magnetizing force that is continuous and the induction discontinuous.

The correct solution is as follows. Defining the vector potential $\boldsymbol{A}$ such that

$$\text{curl } \boldsymbol{A}=\boldsymbol{B}=\mu\boldsymbol{H}, \qquad (1)$$

and satisfying the circuital relation

$$\text{curl } \boldsymbol{H}=4\pi\delta \qquad (2)$$

between the vectors of magnetizing force $\boldsymbol{H}$ and current density δ, together with the further condition that $\boldsymbol{A}$ is a solenoidal vector, namely,

$$\text{div } \boldsymbol{A}=0, \qquad (3)$$

leads to

$$\nabla^2 \boldsymbol{A} = -4\pi\mu\delta \qquad (4)$$

within a current-occupied region and

$$\nabla^2 \boldsymbol{A} = 0 \qquad (5)$$

in a region free from current. We now seek expressions for $\boldsymbol{A}$ suitable for each region, satisfying the necessary condition of continuity at the surfaces of separation between the various regions and containing constants that can be found from the usual conditions of continuity in normal induction and tangential magnetizing force at those surfaces. All this is quite general and will be found in detail in any textbook on vector analysis.

In the present two-dimensional problem the lines of vector potential inside and outside the wire are parallel to its axis and there is obvious symmetry around that axis. If A_i is the vector potential inside and A_e that outside, both being functions of r only, then it is easy to deduce that (4) and (5) become

$$\frac{\partial^2 A_i}{\partial r^2} + \frac{1}{r}\frac{\partial A_i}{\partial r} = -4\pi\mu\delta$$

when $r < a$;

and

$$\frac{\partial^2 A_e}{\partial r^2} + \frac{1}{r}\frac{\partial A_e}{\partial r} = 0$$

when $r > a$,

where $\delta = I/\pi a^2$; these are the conditions (*a*) and (*b*) of Higgins's letter. Also $A_i = A_e$ when $r = a$ and A_i remains finite, which are conditions (*d*) and (*e*). Appropriate forms for A_i and A_e are

$$A_i = -\mu I - \frac{r^2}{a^2}$$

$$A_e = C_2 \log r + C_3$$

as Higgins shows. It is also easy to show that in two dimensions the components of curl in (1) become

$$B_r = \partial A / r\partial\theta \text{ and } B_\theta = -\partial A / \partial r$$

in tangential and radial directions. In the case of a wire of circular section, A_i and A_e are independent of θ, so that the radial induction vanishes everywhere. At the surface of the wire the tangential magnetizing force is continuous; that is,

$$-\frac{1}{\mu}\frac{\partial A_i}{\partial r} = -\frac{\partial A_e}{\partial r} \text{ at } r = a$$

which replaces the incorrect condition (*c*) given by Higgins. Substituting the values found above for A_i and A_e gives $C_2 = -2I$ which, with the further condition that $A_i = A_e$ at $r = a$, makes $C_3 = 2I \log a - \mu I$. Hence finally

$$A_i = -\mu I \frac{r^2}{a^2}$$

when $r \leqq a$

$$A_e = -2I\left(\log \frac{r}{a} + \frac{\mu}{2}\right)$$

when $r \geqq a$

which differs from the value given in my book only in the constant term of A_e. Although my original expressions are incorrect to the extent of this constant they lead to no error in computing the magnetizing force or induction, since these depend on derivatives of vector potential and are in no way affected by the choice of constants required to adjust the continuity of vector potential at the interface. Inspection of the solution given by Higgins shows that his value for A_e must be incorrect since it is consistent with continuity in tangential induction at the surface of the wire, in complete contradiction of the physical facts of the problem.

B. Hague (M'30)

(Electrical engineering department, The University, Glasgow, Scotland)

A Simple Method of Calculating Power Factor

To the Editor:

From my observations and experience with utility companies, there seems to be a definite need among engineers whose work deals with power-system operation for a satisfactory method for the calculation of power factor from kilowatts and kilovolt-amperes. Since this fundamental calculation must be made hundreds of times daily in this type of work, a method, in order to be called satisfactory, must be simple and direct and not require the use of cumbersome equipment. A table of trigonometric functions may be used to advantage, but does not meet the latter requirement.

A method having the advantages mentioned is described herein. It is very simple and direct and may be performed with the aid of any slide rule having the standard *A*, *B*, *C*, *D*, and *CI* scales. Normally only one setting of the slide is necessary.

Let

P = active power in kilowatts
Q = reactive power in kilovolt-amperes
PF = power factor

METHOD

1. Set Q on the *C* scale opposite P on the *D* scale.

2. Note reading on the *A* scale opposite the index of the *B* scale. This reading is equal to $(P/Q)^2$. Since P/Q and also its square may be either greater or less than unity, the decimal point must be located carefully.

3. Mentally add to this reading unity (1.00), and set the indicator to this value on the *A* scale.

4. Read the power factor, PF, at the indicator hairline on the *CI* scale.

THEORY

Consider the following expression for power factor:

$$PF = \frac{P}{\sqrt{P^2 + Q^2}}$$

Rearranging

$$PF = \frac{(P/Q)}{\sqrt{1 + (P/Q)^2}}$$

$$= \text{reciprocal of } \frac{\sqrt{1 + (P/Q)^2}}{(P/Q)}$$

The ratio P/Q is obtained in step 1. The reading on scale *A* is the square of this ratio (step 2). When unity (1.00) is added, the value of the expression under the radical is obtained. The numerator of the fraction is represented by the position on scale *C* of the indicator hairline when set to the value $1 + (P/Q)^2$ on scale *A* (step 3). Now the denominator of the fraction P/Q has been obtained already on scale *D* opposite the *C*-scale index. The value of the whole fraction is the difference logarithmically between the numerator and the denominator. This difference is represented by the point on scale *C* under the hairline of the indicator. Since the reciprocal of this fraction is the power factor, it may be read at once on the *CI* scale.

A few examples are given illustrative of the most important points in connection with this method. In some cases, such as example 2, the slide must be reset to make the final indication fall on the scale.

Example 1.

P = 4,000 kw
Q = 3,000 kva (reactive)

1. Set 3,000 on scale *C* opposite 4,000 on scale *D*.

2. Read 1.78 on scale *A* opposite the left-hand index of scale *B*.

3. Unity added to 1.78 is 2.78. Set the indicator to 2.78 on the left-hand end of scale *A*.

4. Read PF = 0.800 on the *CI* scale at the indicator hairline.

Example 2.

P = 2,400 kw
Q = 700 kva (reactive)

1. Set 700 on scale *C* opposite 2,400 on scale *D*.

2. Read 11.76 on scale *A* opposite the right-hand index of scale *B*.

3. Unity added to 11.76 is 12.76. The slide as now set occupies the wrong portion of the rule to give a reading on the *CI* scale. Therefore, using the indicator to mark the point opposite the index, shift the slide to the right until the left-hand index is at the indicator hairline (11.76 on scale *A*). Now reset the indicator to 12.76 on the right-hand half of scale *A*.

4. Read PF = 0.960 on the *CI* scale.

Example 3.

P = 52 kw
Q = 675 kva (reactive)

1. Set 675 on scale *C* opposite 52 on scale *D*.

2. Read 0.00593 on scale *A* opposite the right-hand index of scale *B*.

3. Unity added to 0.00593 is 1.00593. Set the indicator to 1.00593 on the left-hand end of scale *A*.

4. Read PF = 0.0768 on the *CI* scale. The cipher to the right of the decimal point must be inserted because there are two ciphers to the right of the decimal in the first number (0.00593) read on the *A* scale.

Troy D. Graybeal (A'38)

(Assistant in instruction, department of electrical engineering, Yale University, New Haven, Conn.)

An Operational Solution of Switching Problems

To the Editor:

I. The Heaviside calculus is a convenient means of determining the transient and steady-state current response in a network of impedances on which a set of voltages are imposed at time $t = 0$, providing thereafter no external agency acts on the network. If, however, at some later time additional impedances and potentials are inserted or original units removed, the resulting current distribution cannot be obtained directly. Rather, the switching actions producing the alterations must be simulated by fictitious potentials, the current distribution due to these found, and this latter then combined with that produced by the original driving voltages. This is a clumsy technique; archaic, time consuming, lacking in elegance. The method presented in this paper eliminates the need of these imaginary voltages, thus enabling one to obtain the current response directly from the operational equation.

II. If at $t=0$ voltages are impressed upon a network of impedances devoid of currents the subsequent current flow in a branch of the circuit can be found at once. One seeks a solution* of

$$F(D)y=f(t) \tag{1}$$

which satisfies the boundary conditions

$$D^iy=0 \quad i=(0,1,2\ldots n-1) \text{ at } t=0 \tag{2}$$

The operational solution is

$$y=\frac{f(t)}{F(p)} \tag{3}$$

Consider next the problem of determining the subsequent current flow in a branch of a network of impedances when at the instant $t=0$ the driving potentials producing the currents present (either transient or steady-state) are removed. One must find a solution of

$$F(D)y=0 \tag{4}$$

which satisfies the boundary conditions

$$D^iy=C_i \quad i=(0,1,2\ldots n-1) \quad \text{at } t=0 \tag{5}$$

The required solution† is

$$y=P(t)-\frac{1}{F(p)}[F(D)P(t)] \tag{6a}$$

where

$$P(t)=C_0+C_1\frac{t}{1!}+C_2\frac{t^2}{2!}+\ldots+C_{n-1}\frac{t^{n-1}}{(n-1)!}$$

$$=\sum_{i=0}^{i=n-1}C_i\frac{t^i}{i!} \tag{6b}$$

Finally, consider the problem of finding the subsequent current flow in a branch of a network of impedances in which currents are flowing (either transient or steady-state) when at some instant $t=0$ the network is altered by the insertion of additional impedances, the removal of original impedances, the insertion of new driving potentials, the removal of old driving potentials, or any combination of such variations in the character of the network. The desired expression for the current is the solution of

$$F(D)y=f(t) \tag{7}$$

which satisfies the boundary conditions

$$D^iy=C_i \quad i=(0,1,2\ldots n-1) \quad \text{at } t=0 \tag{8}$$

We shall show that the solution is equations 3 plus 6a.

Note that equation 4 is a special form of equation 7; thus equation 6 is a solution of equation 7 as well as of equation 4. Again, since equation 7 is a linear differential equation, any sum of solutions is a solution; therefore equations 3 plus 6, or

$$y=\frac{f(t)}{F(p)}+\left\{P(t)-\frac{1}{F(p)}[F(D)P(t)]\right\} \tag{9}$$

is a solution of equation 7. Furthermore equation 9 satisfies the boundary conditions (equation 8) for we have

$$D^iy=D^i\frac{f(t)}{F(p)}+D^i\left\{P(t)-\frac{1}{F(p)}[F(D)P(t)]\right\}$$

$$=0(\text{by }2)+C_i(\text{by }5)$$

$$=C_i$$

Hence equation 9 or, more compactly,

$$y=P(t)+\frac{1}{F(p)}[f(t)-F(D)P(t)] \tag{10a}$$

where

$$P(t)=\sum_{i=0}^{i=n-1}C_i\frac{t^i}{i!} \tag{10b}$$

is the desired solution of

$$F(D)y=f(t) \tag{10c}$$

satisfying

$$D^iy=C_i \quad i=(0,1,2\ldots n-1) \text{ at } t=0 \tag{10d}$$

III. In a number of problems $P(t)$ is simply a constant C_0; if so, equation 10a can be considerably simplified. When $P(t)=C_0$ we will have $F(D)y$ in the form

$$F(D)y=\frac{dy}{dt}+y\cdot\text{constant}=\left[\frac{d}{dt}+k\right]y$$

and equation 10a becomes

$$y=C_0+\frac{1}{p+k}\left\{f(t)-\left[\frac{d}{dt}+k\right]C_0\right\}$$

$$=C_0+\frac{1}{p+k}f(t)-\frac{1}{(p+k)}C_0k$$

$$=\frac{1}{p+k}f(t)+C_0-C_0k\frac{1}{k}(1-\epsilon^{-kt})$$

$$=\frac{1}{p+k}f(t)+C_0\epsilon^{-kt} \tag{10A}$$

IV. In this section are worked several examples which serve to illustrate the ease of application and elegance of solution as compared with the method of simulating switching actions by imaginary voltages. The first is a rather trivial example which serves mainly to familiarize one with the notation.

Problem 1. To find the subsequent current y in the circuit of figure 1 which is in steady state when the switch is opened at $t=0$.

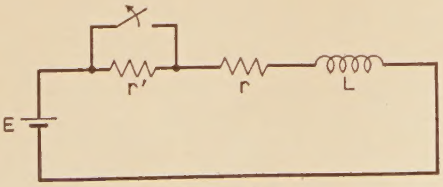


Figure 1

Solution. We must find y which satisfies

$$(r+r')y+L\frac{dy}{dt}=E;\ (r+r')y+Lpy=E;$$

$$y=\frac{E}{r+r'+Lp}$$

and the boundary condition

$$y=\frac{E}{r}=D^0y=C_0 \text{ at } t=0$$

The solution is given at once by equation 10A

$$y=\frac{1}{p+\frac{r+r'}{L}}\frac{E}{L}+\frac{E}{r}\epsilon^{-\frac{r+r'}{L}t}$$

$$=\frac{E}{L}\cdot\frac{L}{r+r'}\left(1-\epsilon^{-\frac{r+r'}{L}t}\right)+\frac{E}{r}\epsilon^{-\frac{r+r'}{L}t}$$

$$=\frac{E}{r(r+r')}\left(r+r'\epsilon^{-\frac{r+r'}{L}t}\right)$$

Problem 2. To find the subsequent current y in the circuit of figure 2 when switch S_1 is closed at $t=0$ and S_2 at $t=T(t'=0=t-T)$.

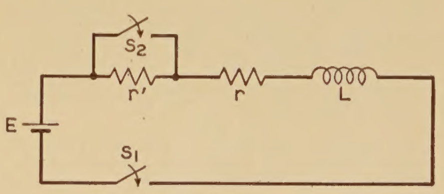


Figure 2

Solution. We are to find y which satisfies

$$ry+L\frac{dy}{dt}=E;\ (r+Lp)y=E;\ y=\frac{E}{r+Lp}$$

and the boundary condition

$$y=\frac{E}{r+r'}\left(1-\epsilon^{-\frac{r+r'}{L}T}\right)=Dy^0=C_0 \text{ at } t'=0$$

From (10A) we have

$$y=\frac{1}{p+\frac{r}{L}}\cdot\frac{E}{L}+\frac{E}{r+r'}\left(1-\epsilon^{-\frac{r+r'}{L}T}\right)\epsilon^{-\frac{r}{L}t'}$$

$$=\frac{E}{L}\frac{L}{r}\left(1-\epsilon^{-\frac{r}{L}t'}\right)+$$

$$\frac{E}{r+r'}\left(1-\epsilon^{-\frac{r+r'}{L}T}\right)\epsilon^{-\frac{r}{L}t'}$$

$$=\frac{E}{r}-\frac{Er'}{r(r+r')}\epsilon^{-\frac{r}{L}(t-T)}-\frac{E}{r+r'}\epsilon^{-\frac{r'}{L}T}\epsilon^{-\frac{r}{L}t}$$

APPENDIX

One must be careful to distinguish between $F(D)$ employed as a *linear operator* and $F(p)$ occurring in the operational formulas. The latter symbolism is familiar, the former possibly not so to many. We illustrate it by the following example. Let $F(D)\equiv\frac{d^2}{dt^2}+\frac{d}{dt}$ operate on ϵ^{at}; we have

$$F(D)\epsilon^{at}\equiv\left[\frac{d^2}{dt^2}+\frac{d}{dt}\right]\epsilon^{at}=a^2\epsilon^{at}+a\epsilon^{at}$$

---

* The notation is summarized in the appendix for the benefit of those to whom it may be unfamiliar.

† See "Linear Differential Equations," E. G. C. Poole, page 31.

With reference to the symbol D^ty we note

$$D^0y=y;\ D^1y=\frac{dy}{dt};\ D^2y=\frac{d^2y}{dt^2};\ \text{etc.}$$

Finally, for the operator used in the solution of the problems

$$\frac{1}{p+k}=\frac{1}{k}(1-\epsilon^{-kt}).$$

THOMAS J. HIGGINS (A'40)

(Instructor in electrical engineering, Purdue University, Lafayette, Ind.)

Books Received •

The following new books are among those recently received at the engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

PHENOMENA AT THE TEMPERATURE OF LIQUID HELIUM. (American Chemical Society Monograph Series No. 83.) By E. F. Burton, H. G. Smith, and J. O. Wilhelm. Reinhold Publishing Corporation, New York, 1940. 362 pages, diagrams, etc., $9\frac{1}{2}$ by 6 inches, cloth, $6.00. Briefly describes liquefaction methods, the measurement of temperature, and the physical properties of liquid and solid helium; discusses superconductivity, specific heats at low temperatures, paramagnetism, temperatures below 1 degree Kelvin, the nature of the superconducting state, and the λ-transformation in liquid helium. Each chapter has a large bibliography.

ELECTRIC CIRCUITS. A First Course in Circuit Analysis for Electrical Engineers. (Principles of Electrical Engineering Series.) By members of the staff of the department of electrical engineering, Massachusetts Institute of Technology; a publication of the Technology Press, Massachusetts Institute of Technology; John Wiley and Sons, Inc., New York; Chapman and Hall, London, 1940. 782 pages, illustrated, $9\frac{1}{2}$ by 6 inches, cloth, $7.50. The staff of the Department of Electrical Engineering at Massachusetts Institute of Technology has for some years been engaged in a program of revising as a unit substantially its entire presentation of the basic technological principles of electrical engineering. This volume, the first of a projected series covering this revised presentation, discusses circuit theory and analysis, with many problems. Appendixes contain tables of the electrical properties of metals, methods of solving linear algebraic equations, tables of units, standards, etc., and a selective bibliography.

APPLIED X RAYS. By G. L. Clark. Third edition. McGraw-Hill Book Company, New York, 1940. 674 pages, illustrated, 9 by 6 inches, cloth, $6.00. Intended for the industrial executive who wishes to know what X rays are, how they may be used, and the ways in which they can be applied to practical industrial problems. The first section discusses the general physics and applications of X radiation; the second covers the analysis of the ultimate structures of materials. Completely rewritten in consideration of the great advances since the previous edition.

ELECTRIC RAILWAYS IN INDIA. By Shiv Narayan. Printed by V. H. Barve at the Aryabhushan Press, Poona City, and published by Brij Narayan, 45 Wellesley Road, Poona, India, 1940. 128 pages, illustrated, 10 by $6\frac{1}{2}$ inches, paper, Rs.4–8. Historical, statistical, and technical information on electric railways, vehicles, and trolley busses in India. Some space is devoted to electric traction in other countries. Glossary of electric traction terms.

ELEMENTS OF UTILITY RATE DETERMINATION. By J. M. Bryant and R. R. Herrmann. McGraw-Hill Book Company, New York, 1940. 464 pages, charts, tables, $9\frac{1}{2}$ by 6 inches, cloth, $4.50. Aims to cover the field of public-utility rate determination, service, and discrimination from the viewpoint of the engineer and manager. Discusses reasons for the regulation of utility rates, describes the methods used to accomplish such regulation, and outlines the practical limitations involved.

GENERAL ENGINEERING HANDBOOK. Edited by C. E. O'Rourke. Second edition. McGraw-Hill Book Company, New York, 1940. 1120 pages, illustrated, $8\frac{1}{2}$ by $5\frac{1}{2}$ inches, flexible leather, $4.00. The purpose of this reference book is to present in one volume the fundamental data relating to all branches of engineering. The data are arranged in 19 sections: mathematics; mathematical tables; physical tables; engineering materials; theoretical mechanics; hydraulics; structural theory and design; plain and reinforced concrete; foundations; topographical and geodetic surveying; route surveying and earthwork; highways; municipal sanitation; machine elements; pumps, compressors, and hydraulic turbines; engineering thermodynamics; heating and air conditioning; fundamentals of electrical engineering; electrical measurements. This edition has been thoroughly revised and rearranged.

RECORDS AND RESEARCH IN ENGINEERING AND INDUSTRIAL SCIENCE. A Guide to the Production, Extraction, Integrating, Storekeeping, Circulation, and Translation of Technical Knowledge. By J. E. Holmstrom. Chapman and Hall, London, 1940. 302 pages, diagrams, etc., 9 by $5\frac{1}{2}$ inches, cloth, 15s. Discusses the nature and methods of technical science and its practical applications; then describes the character, objects, and activities of experimental and technical organizations and societies. The succeeding chapters cover the various ways of searching technical literature, methods of indexing and filing, the expression and transmission of ideas, and the translation of foreign languages, with considerable reference to the author's personal experience. The qualifications and opportunities of the technician are also discussed.

TABLES OF CIRCULAR AND HYPERBOLIC SINES AND COSINES FOR RADIAN ARGUMENTS. Prepared by the Federal Works Agency, Work Projects Administration for the City of New York, as a Report of Official Project No. 765-97-3-10. Arnold N. Lowan, technical director, United States Bureau of Standards, Washington, D. C., 1939. 405 pages, 11 by 8 inches, cloth, $2.00. This volume, the third of a series of mathematical tables, contains values of circular and hyperbolic sines and cosines to nine places of decimals for a range of x from zero to 1.9999 at intervals of 0.0001. Some supplementary and conversion tables are included.

TELEVISION RECEIVING EQUIPMENT. By W. T. Cocking. The Wireless World (Iliffe and Sons, Ltd.), London. 298 pages, illustrated, 8 by 5 inches, cloth, 7s.6d. Explains the principles upon which the modern television receiver works, and deals with the design of its essential parts. Amplifiers, frequency-changers, detectors, time-bases, and sync separators are treated, and consideration is given to cathode-ray tubes and their deflecting systems, and to sound reception and fault finding.

MECHANISM AND THE KINEMATICS OF MACHINES. By W. Steeds. Longmans, Green and Company, London, New York, and Toronto, 1940. 319 pages, diagrams, etc., 9 by $5\frac{1}{2}$ inches, cloth, 18s., $5.00. As a practical aid in the study of mechanisms as mechanical contrivances the author treats only of the kinematics of machines, omitting statics and dynamics. Specific mechanisms considered include straight-line actions, gearing, belts and chains, variable-speed gears, cams, universal joints, and ratchets. Exercises accompany each chapter.

STATISTICAL MECHANICS. By J. E. Mayer and M. G. Mayer. John Wiley and Sons, Inc., New York, 1940. 495 pages, diagrams, 9 by 6 inches, cloth, $5.50. Both classical and quantum mechanics are used as the basis of this elementary treatment of statistical mechanics. Fundamental statistical laws are derived, and the principles of application to various simple energy states discussed. Certain special operations are combined in an appendix. Illustrative problems and glossary of symbols.

NOTIONS COMPLÉMENTAIRES SUR LES TUBES ÉLECTRONIQUES. By M. Chauvierre. Dunod, Paris, 1940. 203 pages, diagrams, etc., $8\frac{1}{2}$ by $5\frac{1}{2}$ inches, paper, 77 frs.; bound, 94 frs. Presents the fundamentals of electron-tube construction, operation, and application. Certain specific problems are considered fully. Graphical methods are used to a considerable extent.

INTRODUCTION TO ELECTRICITY AND OPTICS. By N. H. Frank. McGraw-Hill Book Company, 1940. 398 pages, diagrams, etc., 9 by 6 inches, cloth, $3.50. Intended for second-year students majoring in electrical engineering or physics, this textbook presents the fundamental laws of the electric and magnetic fields, and their elementary applications to circuits, to a study of the electrical and magnetic properties of matter, and to optics. Problems are included with each chapter.

NATIONAL PHYSICAL LABORATORY REPORT FOR THE YEAR 1939. Department of Scientific and Industrial Research. His Majesty's Stationery Office, London, 1940. 100 pages, tables, 10 by 6 inches, paper, 2s.6d. (obtainable from British Library of Information, 50 Rockefeller Plaza, New York, $0.75). In addition to general information concerning the laboratory and its work, this publication presents the reports of the William Froude Naval Laboratory and the departments of physics, electricity, radio, metrology, engineering, metallurgy, and aerodynamics, indicating the state of the current researches.

OUTLINE OF INDUSTRIAL RELATIONS POLICIES IN DEFENSE INDUSTRIES. Princeton University, Industrial Relations Section, Princeton, N. J., June 1940. 47 pages, 10 by 7 inches, paper, $0.75. Brief discussion and reported experiences are presented on: expansion of management organization, recruitment of production workers, training of skilled and semiskilled workers, wages and hours of work, employee-management co-operation in accelerated production. Selected bibliography.

STEAM POWER STATIONS. By G. A. Gaffert. Second edition. McGraw-Hill Book Company, New York, 1940, 592 pages, illustrated, 9 by 6 inches, cloth, $4.50. Chapters 1–17 deal with the construction and performance characteristics of the mechanical equipment, including fuels and feed water. The succeeding chapters, 18–24, cover plant economics and the integration of the machinery, with discussion of steam and binary-vapor cycles. Problems and short bibliographies.

THEORETICAL PHYSICS. Volume III. RELATIVITY AND QUANTUM DYNAMICS, EINSTEIN—PLANCK. By W. Wilson. E. P. Dutton and Company, New York, 1939. 276 pages, diagrams, etc., 9 by $5\frac{1}{2}$ inches, cloth, $5.75. The final volume of this text, like the preceding volumes, presents physical theory as a coherent logical unity. The discussion of relativity passes from Einstein's special theory to the general theory. The development of the quantum theory starting with Planck, takes in wave mechanics, matrix mechanics, and electron theory. Contains a discussion of the analogy between geometrical optics and Hamiltonian dynamics, and its application to quantum dynamics.

MATHEMATICAL RECREATIONS AND ESSAYS. By W. W. Rouse Ball, revised by H. S. M. Coxeter. Eleventh edition. Macmillan and Company, Ltd., London; Macmillan Company, New York, 1939. 418 pages, illustrated, 8 by 5 inches, cloth, $2.75. Covers arithmetical and geometrical problems, magic squares, chess, and playing card recreations. Cryptographs and ciphers are discussed and the feats of various calculating prodigies briefly described. Several chapters have been enlarged in this edition, a chapter on polyhedra replaces one on mechanical problems, and string figures have been omitted.

BIBLIOGRAPHY ON INDUSTRIAL RADIOGRAPHY. Including Addenda I—April 1940. Document 1139. By H. R. Isenburger. American Documentation Institute, Washington, D. C., photographic copies, 8 by 6 inches, paper, $10.70. Contains references to over 200 articles on the industrial uses of radiography. The list supplements the bibliography published in St. John and Isenburger's "Industrial Radiography" and consists of articles published since its appearance in 1934, with a few omitted from the book. It covers the literature to April 1940.

ARTIFICIAL LIGHT AND ITS APPLICATION. Westinghouse Electric and Manufacturing Company, Westinghouse Lamp Division, Bloomfield, New Jersey, 1940. 296 pages, illustrated, 11 by $8\frac{1}{2}$ inches, paper, apply. The history of artificial lighting is briefly surveyed, the units and methods of measuring light are described, and vision and color are discussed as introduction to drafters which describe modern applications of lighting for all purposes, from ordinary home illumination to photographic work and germicidal radiations.

ELECTRIC CIRCUIT AND MACHINE EXPERIMENTS. By F. W. Hehre and J. A. Balmford. John Wiley and Sons, New York, 1940. 279 pages, diagrams, etc., 9 by 6 inches, paper, $2.00. Presents a set of experiments designed to cover elementary work in electric machines. The necessary apparatus, laboratory procedures, and safety precautions are described, and an outline of theory precedes each group of experiments.

ELECTROCAPILLARITY. By J. A. V. Butler. Chemical Publishing Company, New York, 1940. 208 pages, illustrated, 9 by $5\frac{1}{2}$ inches, cloth, $5.00. Deals with potential differences at electrified interfaces, the origin and nature of the effects that arise therefrom, and with electrode equilibria and kinetics. Reviews the work of the past 15 years, touching many subjects, from the behavior of proteins to the passivity of metals.

ELECTRONIC PROCESSES IN IONIC CRYSTALS. By N. F. Mott and R. W. Gurney. Oxford University Press, New York; Clarendon Press, Oxford, England, 1940. 275 pages, illustrated, 10 by 6 inches, cloth, $5.50. Aims to develop the theory of the movement of electrons in ionic crystals, and to interpret experimental facts in terms of the theory. The Born theory of cohesion in ionic crystals and the Wagner-Schottky theory of ionic conductions in solids are described as an introduction. The succeeding discussions cover the absorption of light by ionic crystals, with the resulting photoconductivity and luminescence; the properties of semiconductors; and the insulating properties of nonconducting materials, including breakdown in high fields. Chemical reactions in solids are briefly considered in the final chapters.